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MAY—JUNE, 1922

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A REVIEW OF OIL AND GAS POOLS IN NORTH LOUISIANA TERRITORY

J. P. D. HULL AND W. C. SPOONER

INTRODUCTION

Natural gas was first recognized in seeps near Red River in Caddo Parish, Louisiana, many years ago, a long time before wells were drilled in that territory for oil or gas. The development of Caddo, the first oil and gas pool, did not begin, however, until 1904. In 1912 and 1913 gas and oil were discovered in commercial quantities in De Soto Parish, and since that time many pools have been found and prospects are bright for the discovery of many more.

The Louisiana State Geological Survey began collecting information on oil and gas prior to 1900, but owing to lack of funds, continuous work has been impossible; in fact there has been no State Survey for more than a decade, since Prof. G. D. Harris of Cornell University had charge of the Louisiana work.

Four publications of the U. S Geological Survey furnish the principal geological information used as a basis for work in the North Louisiana-South Arkansas fields, namely; Veatch's "Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas," Professional Paper 46, 1906, Harris' "Oil and Gas in Louisiana," with a Brief Summary of their Occurrence in

J. P. D. Hull, Geologist, Louisiana Oil & Refining Co., Shreveport, La.
W. C. Spooner, Geologist, Arkansas Natural Gas Co., Shreveport, La.

Adjacent States", Bulletin 429, 1910, Matson's "The Caddo Oil and Gas Field, Louisiana and Texas", Bulletin 619, 1916, and Matson and Hopkins', "The De Soto-Red River Oil and Gas Field, Louisiana", Bulletin 661-C, 1917.

Three more recent publications are "The Sabine Uplift, Louisiana", by Sidney Powers, Bulletin American Association Petroleum Geologists, Vol. 4, No. 2, 1920, "The Monroe Gas Field, Ouachita, Morehouse and Union Parishes, Louisiana", by H. W. Bell and R. A. Cattell, U. S. Bureau of Mines, published July, 1921, as Bulletin 9 of the Department of Conservation, State of Louisiana, and "The Haynesville Oil Field, Claiborne Parish, Louisiana", by W. W. Scott and Ben K. Stroud, published as Bulletin 11 of the State Department of Conservation in co-operation with the U. S. Bureau of Mines, Jan., 1922.

GENERAL GEOLOGY

The area here designated "North Louisiana Territory" covers the adjacent parts of East Texas to include the Bethany gas pool and the adjacent parts of South Arkansas to include the El Dorado oil and gas pool. The southern limit of the area may be considered as latitude 31° North corresponding with Veatch's map[1].

The following table shows the sequence of formations in this territory:

Table of Formations

System	Series	Group	Formation
Quaternary	Recent		
	Pleistocene		Port Hudson
Tertiary	Pliocene		Lafayette
	Oligocene		Fleming Clay
			Catahoula
			Vicksburg
	Eocene		Jackson
		Claiborne	Cockfield
			St. Maurice
			Wilcox
			Midway

[1]Veatch, A. C., U. S. Geol. Survey, Prof. Paper 46.

Cretacious	Gulf (Upper Cretaceous)		Arkadelphia Clay
			Nacatoch Sand
			Marlbrook Marl
		Austin	Annona Chalk
			Brownstown Marl
		Bingen	Blossom Sand
			Eagle Ford Clay
			Woodbine Sand
	Comanche (Lower Cretaceous)	Washita	Denison
			Fort Worth Limestone
			Preston
		Fredericksburg	Goodland Limestone
		Trinity	

The surface formations over the oil and gas pools in the Louisiana-Texas-Arkansas territory are restricted to the Eocene and Pliocene series of the Tertiary system, and the Pleistocene and Recent series of the Quaternary system, except the Cretaceous outcrops on the several truncated salt domes. These unconsolidated sediments, Wilcox, St. Maurice, Cockfield, Lafayette, and Port Hudson, have distinctive features where typically developed, but they are commonly indistinguishable one from another because of their origin from similar sources and because of subsequent reworking.

STRUCTURE

Practically all of the formations penetrated by the drill in North Louisiana outcrop in Arkansas within 100 miles, more or less, north and northwest of the pools. The regional dip is south and southeast from the Ouachita Mountain Uplift to the Gulf of Mexico and Mississippi River. The Cretaceous deposits rest on the eroded Paleozoic floor at a very gentle angle of dip where undisturbed by deformation, but these undisturbed places representing most closely the original deposition are almost the exception to the rule, for the whole region is marked by uplifts, domes, folds, and faults with accom-

panying synclines and troughs which all together make a subsurface contour map of rugged and broken appearance.

A line on top of the Nacatoch formation drawn southeast from the outcrop in Arkansas drops about 2370 feet in 57 miles (41 feet per mile) to the Louisiana state line; rises 300 feet in 8 miles to the top of the Haynesville structure; drops 100 feet in 10 miles between Haynesville and Homer; rises 1000 feet in 5 miles to the top of the Homer dome; and going farther south, drops 1200 feet in 5 miles, or 240 feet per mile, east of Minden.

These distinct uplifts and domes which are considered as structural deviations from the normally gentle regional dip may be described in four groups and classified as: (1) Sabine Uplift, (2) Ouachita Uplift, (3) Isolated Domal Structures and (4) Eroded Salt domes.

The Sabine Peninsula, or Uplift, was describbed as such by Harris[2] in 1907 and 1910.

A recent paper by Sidney Powers[3] was published in the Bulletin of this Association in 1920. The uplift occupies the northwestern part of the state, including the parishes of Caddo, Bossier, De Soto, and Red River, and extending across the state line into Marion, Harrison, Panola, and Shelby counties, Texas. On this structural uplift are the Caddo oil and gas pool, Shreveport gas pool, Elm Grove gas pool, De Soto-Red River oil and gas pool, Bethany gas pool, and Bellevue oil pool.

The Ouachita Uplift is much less extensive than the Sabine Uplift and not such a high structure. It includes parts of Ouachita, Morehouse, and Union parishes in the northeastern part of Louisiana, 75 miles east of the Sabine Uplift. The Monroe gas pool is on the Ouachita Uplift.

There are three isolated folds and domes between the two large uplifts: Homer, Haynesville, and El Dorado. These will be described separately.

The fourth group of pronounced domes comprises the sa-

[2]Harris, G. D., Rock Salt in Louisiana, Geol. Survey of La., Bull. 7, 1907, Pl. 24; Oil and Gas in Louisiana, U. S. Geol. Survey, Bhll. 429, 1910.

[3]Powers, Sidney, The Sabine Uplift, Louisiana, Am. Assn. Petrol. Geol., Bull., Vol. 4, No. 2, 1920.

lines, or salt works, rising from synclines between the two large uplifts and south of the isolated productive domes and folds. The salines are eroded, non-productive, steeply dipping domes in Bossier, Bienville, Natchitoches, and Winn parishes.

STRUCTURAL EVIDENCE

In working out sub-surface Cretaceous structure in advance of drilling beneath an area made up of unconsolidated Tertiary deposits mantled by Quaternary and Recent sands and clays, the geologist must consider the possible evidence of everything in sight and then be ready to discard all of it when subsequent drilling disproves it.

The surface features he generally considers in mapping wild cat areas are stratification, dips, inliers, topography, stream courses, springs, and vegetation, besides the stratigraphy and petrology of the formations.

When it is known that most of the production comes from depths ranging from 1500 to 3000 feet in Cretaceous beds that are separated from the surface by erosional unconformities, overlaps, faults, and lens pinching, it is not surprising that some geologists have considered the unconsolidated cross-bedded surface as worthless in attempting to determine structure. Nevertheless judicious use of these surface indications has enabled geologists to locate a number of valuable producing structures such as Haynesville which is less than a year old in March 1922 is producing about 90,000 barrels a day and is less than one fourth drilled up, exclusive of at least two sands still to be tested.

OIL POOLS

CADDO POOL

The Caddo oil and gas pool may be called a field in which there are several pools. The south end of the field is at Mooringsport, 15 miles northwest of Shreveport. Its area is about 180 square miles on the northern end of the Sabine Uplift. Like many other parts of the uplift it possesses no topography peculiarly distinctive of an uplift or favorable oil structure. Much of the surface is swamp land and lake bottom, though the rolling hills rise 180 feet above Caddo Lake. The surface

geology is on the whole non-committal Wilcox and Quaternary. Gas seeps caused the search for oil and gas and drilling found the structure. It is one of the higher parts of the Sabine Uplift but has a structural relief of only 200 feet. The field is spotted irregularly, probably because of small local folds and faults that are impossible of determination except by drilling.

Caddo produced the first gas in Louisiana,—from the Nacatoch sand from 800 to 1,000 feet below the surface. Oil is produced from the Woodbine sand from depths of 2,200 to 2,275 feet, and from the Trinity formation at 2,900 feet, more or less. Caddo's production dropped from 10,000,000 barrels in 1913 to 6,000,000 barrels in 1917, but in 1918 development in the Pine Island pool raised the output to 11,000,000 barrels. In 1921, the production was again below 6,000,000 barrels but the Trinity formation in the same Pine Island district is now providing a new source of high gravity oil and Caddo still has surprises to bring forth, as the field is by no means drilled up. It has produced to date (1906 through 1921) 86,450,848 barrels, exclusive of fuel oil. It has been estimated that Caddo has an ultimate production of 122,000,000 barrels of which 118,000,000 are probable and 4,000,000 are possible.

DE SOTO-RED RIVER POOL

The De Soto-Red River pool is 45 miles southeast of the Caddo pool, at the southeast end of the Sabine Uplift. It is on both sides of Red River in De Soto and Red River parishes. The topography, areal and structural geology, and drilling conditons are almost the same as in the Caddo pool, except that the pool is divided by a fault with a 200-foot down-throw to the south. Gas occurs in the Nacatoch, but practically all of the oil has been produced from the Woodbine, which lies at a depth of 2,500 to 2,700 feet. The field has produced (1914 through 1921) 37,837,360 barrels, less than half the amount of Caddo. The ultimate yield is estimated as 63,000,000 barrels of which 60,000,000 are probable and 3,000,000 are possible.

BELLEVUE POOL

The Bellevue pool is not only the newest pool on the Sabine Uplift but it is also the youngest oil pool in the North Louis-

iana territory. It is at the northeastern edge of the Uplift, in Bossier Parish, 15 miles northeast of Shreveport. The surface is almost flat with a general elevation of 215 feet above sea level, and appears to be quite the opposite to what it really is, the highest productive structure in the region.

Although bedding planes for structural mapping are scarce and doubtfully dependable, the surface geology is more clearly indicative of sub-surface structure here than in almost any other North Louisiana pool, excepting the eroded salines. True, it has required years to locate the high part of the dome, but this structural inlier has been known in print since 1905 when it was mapped by Veatch.[4] A stratigraphic sequence of Eocene formations may be followed from older Wilcox outward through overlying St. Maurice and Cockfield of the Claiborne formation to the younger Quaternary sands surrounding the pool, thus exhibiting a truncated dome whose exposed top occupies a whole township of 36 square miles.

The productive part, however, as developed to date, underlies but one square mile. Oil of about 20 gravity flows from the Nacatoch sand from depths as shallow as 63 feet below sea level or 290 feet below surface. Some gas also occurs with the oil.

The Bellevue structure has a relief of 700 feet on top of the Sabine Uplift, forming an exceptionally high dome on the end of a nose eastward from the main part of the uplift. On its east side, however, the Bellevue dome drops 1,800 feet in 6 miles to a deep syncline southwest of the Homer pool. This is the highest productive dome in the North Louisiana territory where the Cretaceous sands are sealed. It is more than 600 feet higher than Homer, both referred to sea level. It is, therefore, an ideal place to test each of the four Cretaceus sands known to be productive elsewhere in the territory, namely; Nacatoch, Blossom, Woodbine, and Trinity. Only one hole has been drilled into all these formations and it did not find production, though it went to a depth of 4,052 feet. This was

[4]Veatch, A. C., Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas, U. S. Geol. Survey, Prof. Paper 46, Pl. III, 1905.

drilled by the Texas Company on the southwest slope of the structure.

Bellevue was discovered to be commercially productive in November, 1921, by R. O. Roy's persistence in drilling and by J. Y. Snyder's insistence in geology. About 15 wells have perhaps more than 50,000 barrels of 20 gravity oil in storage awaiting completion of the Standard Oil Company's pipe line. If production corresponds with the size of the dome and accessibility of the sands. Bellevue should have an ultimate production of 41,500,000 barrels.

HOMER POOL

The Homer pool was the first pool discovered off the Sabine Uplift, in 1919. It is in the western part of Claiborne Parish, 45 miles northeast of Shreveport, and underlies an area of 5 square miles.

Homer is one of the three isolated domes (El Dorado, Arkansas, and Haynesville, Louisiana, being the other two) having topographical and geological conditions different from the pools on the Sabine Uplift. It is a distinct structural dome approximately underlying a topographically high surface which is not only an interstream ridge but is a high divide from which there is drainage in all directions.

The rolling to hilly surface ranges from 225 to 325 feet above sea level. The surface formations are either Wilcox or Claiborne with some exposures of stratification that indicate an uplift. Sub-surface structure based on the Nacatoch sand shows a structural relief of 1,200 feet, from 700 feet below sea level on top of the dome to 1,900 feet 5 miles south of this point. The dome is broken east and west through the center by a fault with a downthrow of 300 to 400 feet on the south side. Both Nacatoch and Blossom sands, separated from each other by an interval of 700 feet, produce at Homer. The pool is practically drilled up, though the Woodbine sand has been tested in only a few places by deeper drilling. Though only 3 years old, Homer has produced 37,639,251 barrels, or as much as the De Soto-Red River pool, that is 8 years old. It is estimated that Homer has an ultimate production of 64,000,000 barrels.

EL DORADO POOL

The El Dorado pool is situated in the central part of Union County, Arkansas, and lies approximately 25 miles northeast of the Haynesville pool. The proven oil and gas area comprises 20 square miles, or 12,800 acres.

The topography of the region is very similar to that o Northern Louisiana, the surface features ranging in elevation from 100 feet, on the wide valley floor of Ouachita River, to about 300 feet on the hill summits.

The strata exposed consist chiefly of soft clays, sands, lignites, and gravels of Tertiary age. Superficial deposits of the Quaternary period cover the valley floors of Ouachita River and smaller streams. The section includes the Upper Claiborne formations of the Eocene Tertiary to the Nacatoch sand of the Upper Cretoceous found at an average depth of 2,150 feet.

Surface structure is very misleading. The Pleistocene covering the Tertiary deposits renders the work on clays, gravels, and lignites very doubtful. Reversals show surface structures which do not check the sub-surface conditions.

Sub-surface structure is based on top of the Nacatoch or producing horizon. In general it has a north-south trend dipping to the east. Since no particular structure is depicted by means of reversals, accumulation here is principally accounted for by sand conditions. From drilling records to date the sand seems to grade into shales from east to west.

Five-foot contours drawn within the approximate forty-foot dip in the producing horizon show the area to be noticeably disturbed. The pay sand which is principally a sandy shale ranges from one to thirty feet in thickness accompanied by a bad water and basic sediment content also very variable.

Development so far has covered a proven area of 12,000 acres. To date there have been 1,249 locations made of which 757 have come in as producers, 222 are either dry or drilling below 2,100 feet, and 270 are spudded.

Of the producers nearly all were oil wells with either a little or no gas and with varying amounts of water and basic sediment. The initial production of wells falls off very fast due to

these conditions. There are a few scattered gas wells.

Total amount of shipments and storage for the year 1921 commencing March 24th was 10,819,265 barrels. The oil has a gravity of 33.8 degrees Baume.

HAYNESVILLE POOL

The Haynesville pool comprises an area of about 8 square miles in T. 23 N., R. 8 W., Claiborne Parish, just south of the Louisiana-Arkansas state line. It is 50 miles northeast of Shreveport and 12 miles north of the Homer pool. The surface is an interstream divide with a local relief in the field of 100 feet, ranging from 260 to 360 feet above sea level.

The formations exposed are Upper Claiborne (Cockfield) and the common Quaternary mantle of sand and gravel. The exposures of Cockfield sandy clays show a remarkable number of dips which outline the underlying structure on the producing sand (Blossom).

Haynesville is a pronounced but low structure as compared with Homer, being 900 feet lower and having a relief of only 300 feet on the Nacatoch as compared with 1,200 at Homer. Contours on the producing Blossom sand show a local relief of 80 feet in the producing area. No well-recognized fault has yet been found.

Since the spring of 1921, more than 200 wells have been drilled. These now produce 90,000 barrels per day. The field as developed in the Blossom sand is less than one fourth drilled up, has produced about 6,000,000 barrels of high gravity oil and is probably good for an ultimate production of 57,000,000.

The field has been well described by W. W. Scott and Ben K. Stroud.[5]

GAS POOLS

The more notable developments of gas territory in North Louisiana during 1921 have been the discovery of gas in Webster parish and the extension of the Monroe gas pool.

CADDO POOL

The Caddo pool takes its name from the parish wherein located. It is divided into several districts of which the Vivian

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[5]Scott, W. W., and Stroud, Ben K., The Haynesville Oil Field, Claiborne Parish, Louisiana, Bull. 11, State of Louisiana Dept. of Conservation, in co-operation with the U. S. Bureau of Mines, January, 1922.

district in T. 22 N., R. 15 W., and the Oil City district in T. 20 N., Rs. 15 and 16 W., are the more important gas producing areas.

The Nacatoch sand at a depth of 800 to 1,000 feet is the important gas producing horizon.

During the early years of development in the Caddo field a vast volume of gas was wasted through improper drilling and wasteful methods of operation. In 1910, the first year of which records were available, the rock pressure had declined to 190 pounds; 20 pounds in 1920; 14 pounds in 1921; and 10 pounds January 1st, 1922, nearly making the depletion of the pool.

The gas available before completely exhausted probably does not exceed one billion cubic feet.

ELM GROVE POOL

This pool, also known as the Bossier pool, is situated in T. 16 N., Rs. 11 and 12 W., Bossier Parish.

The Wilcox formation is found at the surface throughout the field. Two sands are productive; the Nacatoch sand from a depth of 800 to 900 feet and the Woodbine sand from a depth of 2,450 to 2,550 feet. Neither sand is productive throughout the pool. The Nacatoch production is confined principally to the western part of the pool, while the Woodbine production is principally on the east side.

The surface dips in the Wilcox indicate a structure, but it is by sub-surface work only, that the structure can be outlined with any degree of accuracy. Based on the Nacatoch sand the structure takes the form of a dome slightly elongated northeast and southwest. Production is obtained as low as 70 feet down the dip from the apex of the dome.

About 160 wells have been drilled in this field, 31 of which were dry holes. At the present time, there are 51 active wells, 28 producing from the Nacatoch and 23 from the Woodbine sand.

The initial rock pressure was 1,100 pounds for the Woodbine and 400 pounds for the Nacatoch, while the present rock pressure is 305 pounds and 245 pounds respectively for these sands.

To January 1st, 1922, the Nacatoch sand had produced 36,-

000,000,000 cubic feet and the Woodbine sand 51,000,000,000 cubic feet.

The reserve gas remaining in the field is estimated as approximately 50,000,000,000 cubic feet.

BETHANY GAS POOL

This pool is situated mainly in Panola County, Texas, but also includes a part of Harrison County, Texas, and Caddo Parish, Louisiana.

The Wilcox formation is exposed at the surface. Four different sands produce the gas, as follows:

Nacatoch sand at an average depth of 1,500 feet.
Blossom sand at an average depth of 1,725 feet.
Woodbine sand at an average depth of 2,650 feet.
Deep Gas sand at an average depth of 2,950 feet.

The Nacatoch sand production appears to extend throughout the pool; the Woodbine sand production is limited to the southern part; the deep sand has been developed only in the northern part; and the Blossom sand to this time has been developed only in the western part of the pool. Future development may prove the Blossom sand production to extend over a considerable area.

The surface dips in connection with the topography and drainage indicate a structural high in this area. Sub-surface mapping shows a northeast-southwest trending anticline with a superimposed dome on the north end and one on the south end. Additional data will probably show a sub-surface fault between the two domes.

To date 52 wells have been drilled in this pool, 22 of which are gas wells and the remainder dry holes or small abandoned oil wells. The gas wells are producing from the different sands as follows: Nacatoch sand 6 wells, Blossom sand 3 wells, Woodbine sand 7 wells, Deep gas sand 6 wells. The initial rock pressure was 450 pounds for Nacatoch sand, 840 pounds for Blossom sand, 1,050 pounds for Woodbine sand and 1,200 pounds for Deep gas sand.

Up to January 1st, 1922, gas had been taken only from the north part of the pool and 810,000,000 cubic feet had been removed from the Nacatoch and 3,150,000,000 cubic feet from

the Deep gas sand. In the corresponding time the rock pressure declined to 200 pounds for the Nacatoch and 300 pounds for the Deep sand.

The wells producing from the Woodbine and Blossom sands have not been connected to the pipe line and no information is available as to the future life of these wells.

It is estimated that Bethany will produce 75,000,000,000 cubic feet of gas before depleted.

MONROE GAS POOL

This pool covers an area of more than 250 square miles in Union, Morehouse, and Ouachita parishes. It is about 110 miles east of Shreveport, Louisiana. The greatest development to date has been in T. 19 N., R. 4 E., and T. 20 N., R. 4 E.

Along Ouachita River and Bayou Bartholemew the average surface elevation is 80 feet. West of Ouachita River the elevation increases to 150 feet.

The larger part of the Monroe gas pool is covered with recent formations of Pleistocene and Quaternary age. In a few places rocks of Eocene age are found, but due to the lithologic similarity of the Eocene formations, it is difficult to determine their exact age.

Sub-surface geology based on well logs indicates an uplift in this region comparable in magnitude to the Sabine Uplift in the western part of the state. This uplift, which has been termed the Ouachita Uplift, trends in the same general direction as the Sabine Uplift. Local domes elongated northeast and southwest are superimposed upon the major fold. Drilling to date has not defined the limits of this uplift.

The production is obtained from a depth of 2,000 to 2,300 feet from an horizon similar to the Annona Chalk. The initial rock pressure was 1,050 pounds.

About 143 wells have been drilled and 82 are producing gas wells. It is estimated by the Department of Conservation of Louisiana that 110,000,000,000 cubic feet have been used and lost through wild wells. In Bulletin 209 published by the Department of Conservation, H. W. Bell and R. A. Cattell estimate the total volume of gas in the field at 4,750,000,000,000 cubic feet.

WEBSTER PARISH

The area of particular interest owing to recent completions of gas wells is that part of Webster Parish comprising T. 23 N., Rs. 9, 10 and 11 W. The topography and geology of this area is similar to that of the Haynesville oil pool immediately to the east.

Three producing gas wells have been completed in this area as follows: in 20-23-9, Sinclair Oil Co.'s Mayfield No. 1, 7 mil.; in 34-23-11, Lloyd Harris et al., Pine Woods No. 1, not gauged; and in 1-22-10, Portland Synd., Munn No. 1, 44 mil. Dry holes have been drilled in all directions from these producing wells, but not in sufficient numbers to determine the probable producing area which, however, appears to be large. The production is from the Blossom sand as at Haynesville.

OTHER GAS PRODUCING AREAS

The Shreveport-Cross Lake pool situated in T. 18 N., R. 14 W., and T. 17 N., R. 14 W., is partially depleted as is also the Cedar Grove pool in T. 17 N., R. 13 W.

The Red River-De Soto pool is practically depleted, furnishing only enough fas for field use.

SUMMARY

After watching new oil and gas pools come in one after another in the North Louisiana-East Texas-South Arkansas territory, the observer is greatly encouraged in looking for new pools beneath the large areas in these states where wildcatting is only beginning to be done.

A tabulated summary of the pools and their production is given below:

Summary of pools and pipeline runs in the North Louisiana Territory to January 1, 1922

Pools	Age (Years)	Acreage Drilled	Barrels Pipeline Runs	Barrels per Acre
Caddo	16	31,000	86,500,848	2,790
De Soto-Red River	8	10,000	37,837,360	3,783
Homer	3	3,000	37,639,251	12,546
El Dorado	¾	4,000	10,500,000	2,625
Haynesville	2/3	1,400	3,000,000	2,142
Total		49,409	175,477,459	3,552

THE ELDORADO ARKANSAS OIL FIELD AND ITS RELATION TO NORTH LOUISIANA STRUCTURES.

A. F. Crider

INTRODUCTION

For a number of years the state line between Arkansas and Louisiana was fixed in the minds of the majority of oil operators, and not a few geologists, as the boundary between productive and non-productive oil and gas territory. This idea did not develop without some basis for the conception. Some of the first geologic reports, by the best of authorities, separated the two areas by a pronounced fault. The oil-bearing horizons on the north side of this fault were believed to be in a low regional syncline and would contain salt water instead of oil or gas. The first wells drilled on the Arkansas side rather strengthened this general belief.

It took the cooperation of the geologist and the operator to overcome this prejudice, and to give this region the consideration it deserves. It is an item of scientific interest that the first producing oil field of Arkansas was discovered and recommended by a geologist, Mr. J. J. Victor. His conclusions were concurred in by other geologists who recommended the territory to their respective companies, and by Mr. K. C. Heald, of the U. S. Geological Survey.

It is not known what led Mr. Victor and the other geologists to look for a structure at ElDorado. They no doubt believed that the same forces that produced the primary and secondary folding of the Osage district in Oklahoma, and produced the structures at more or less regular intervals, operated in the Coastal Plain formations under modified conditions, and after determining the checkerboard system of folding in the producing fields in Louisiana it was a logical place to look for a fold.

STRATIGRAPHIC SECTION

It is not the purpose of this paper to discuss the extent and operating conditions of the ElDorado field. However, a few words in regard to the stratigraphy and the nature of the

structure will not be irrelevant to the subject matter under discussion. Various opinions have been expressed as to the stratigraphic horizon of the producing sand in the ElDorado field. A study of the ElDorado logs shows the Wilcox formation to extend to a depth of 1200 to 1300 feet. The base of the Wilcox is well defined by a bed of lignite in most of the wells. Below this comes 150 to 200 feet of limestone, shale, and marls of Midway age. The Midway forms the most striking key horizon of north Louisiana and South Arkansas oil territory. The Midway outcrops near Benton, Arkansas, about 90 miles north of ElDorado.

Directly underlying the Midway comes 500 to 600 feet of Arkadelphia shales of a dark color at the outcrop but light grey in some places in Louisiana.

The interval between the base of the Wilcox and the producing sand in the ElDorado field is 800 to 900 feet. This corresponds aproximately to the interval between the Wilcox and the Nacatoch horizon in north Louisiana. A hard limestone, about 150 feet above the producing sand, forms a distinctive marker for the driller in determining the position of the pay sand.

Fossils obtained from some of the wells and a study of some of the minute forms from cuttings, point conclusively to the Nacatoch age of the ElDorado producing sand.[1]

Below the Nacatoch sand comes about 900 feet of chalk, shales and sands of Annona and Brownstown age. At a depth of 3000 feet, in the Cooper Henderson well, on the Hammond farm in Sec. 19, T. 17 S., R. 15 W., a bed of sand and gravel was encountered which apparently marks the base of the Upper Cretaceous.

The gravels from this horizon are mostly quartzite and chert, and range from large sand grains to pebbles one inch or more in diameter. They are associated with pink shales and the gravels themselves have decided pink color when broken open. These gravels are not present at this horizon

[1]Since this paper was written, in a press Bulletin issued by the U. S. Geological Survey, Mr. L. W. Stephenson states that fossils, sent him by Mr. H. N. Spofford of the Gladys Belle Company of ElDorado, from the producing horizon, are of undoubted Nacatoch age.

throughout north Louisiana and south Arkansas. They have been reported in a number of wells but no samples other than those from the Cooper Henderson well have been examined by the writer.

The pink clays and sands similar to those associated with the red gravels in the Cooper Henderson well have been found approximately 300 feet below the gas sand in the Monroe field. They have likewise been found to underlie the Bull Bayou, Bethany, Caddo, the shallow Bossier, and Homer fields. These pink or red shales are believed to represent the Lower Cretaceous here as they doubtless do in the Empire well on the Hatchetigbee anticline in Washington County, Alabama, and in a number of wells in the peninsula of Florida, as pointed out by Bostick.[2]

STRUCTURE

The development of the ElDorado field has revealed a long narrow structure with an anticlinal axis extending in a slightly west of north and east of south direction paralleling a fault on the east which cuts off production abruptly to the east. Just east of the fault, and the associated salt water-bearing syncline, is a second structural high area, the outline of which has not been clearly defined. The development of this part of the field will doubtless show the influence of a secondary fold.

SOURCE OF OIL AND GAS

It is well known, to the student of the Coastal Plain formations of Louisiana and the other southern states, that the entire thickness of the Tertiary is lacking in bituminous shales. The Claiborne and Wilcox shales are generally found to be of a light grey to chocolate color. The latter is due to the presence of lignitiferous material. The Arkadelphia shales have more the appearance of oil-bearing shales than the Claiborne or the Wilcox shales but they can be discarded without argument as the source of any great amount of oil and gas. The only possible source of oil and gas in the Cretaceous is the Brownstown marl, and, in a few instances, as in the Elm Grove gas field, it is believed to be the source of the oil which

[2]Bostick, J. W., Oil Weekly, May 1920.

occurs in the so-called Blossom sand. But it is not conceivable, without further evidence and some distillation tests on this marl, that it can be the source of any great amount of hydrocarbons from the Nacatoch to the Glen Rose horizon.

The red shales which are believed to be of Lower Cretaceous age and which have been found to underly all of the producing fields of north Louisiana and south Arkansas, are even less likely to be the source of oil and gas than the Upper Cretaceous or the Tertiary. There is a lack of evidence by writers on Coastal Plain geology that oil and gas are indigenous to the sands in which they occur.

From whence then, has come the immense deposits of oil like that at Homer, Haynesville, Bull Bayou, Caddo, and ElDorado? All of the above mentioned fields, as well as Bethany, Elm Grove, Monroe, and the shallow Bossier fields are believed to be on separate buried hills which were doubtless in existence as such, previous to the subsidence and encroachment of the Cretaceous sea. Subsequent folding affected all Cretaceous and Tertiary sediments.

The deep synclinal trough which separates Homer from the Bossier field strengthens the belief that each field is a separate and distinct uplift with underlying hills of older rocks. The general trend of these buried hills roughly parallels the line of folding in the older rocks in south central Arkansas. The amount of uplift between the shallow Bossier field and the synclinal trough between there and Homer, as shown by the Nacatoch sand, is approximately 1700 feet.

Logs of wells drilled on these uplifts show a decided thinning of the Lower Cretaceous sediments. The existence of buried mountains and the thinning of the Cretaceous column leads easily to the inference that these old uplifts may contain Pennsylvanian shales or perhaps shales of older formations which are believed to be the source of the hydrocarbons in the north Louisiana and south Arkansas fields. Up to the present time no well in any of the producing fields has penetrated the older rocks so that it is not possible to ascertain the nature of these older formations. That these older shales do contain hydrocarbons is shown by the presence of asphalt in the Carboniferous rocks of Pike County, Arkansas,

and in Carboniferous and older rocks in eastern Oklahoma and near Mena, Ark.[3]

The Pre-Cretaceous rocks may have been fissured previous to the deposition of the Cretaceous and later sediments. In some of the fields as ElDorado, Homer, Bull Bayou, and Caddo later forces produced faulting which extended through the entire thickness of Cretaceous and Tertiary or it may be that the faulting has all taken place since the end of the Tertiary period. At any rate, these fissures extend downward to the source of the hydrocarbons.

As a general proposition the faulted structures produce oil, or gas and oil; the unfaulted structures produce gas only. The hydrocarbons no doubt have a common origin and are not indigenous to the sands in which they occur. In a faulted structure as at Homer, Bull Bayou, Caddo and ElDorado, the source of the oil is from some common source below where it is at present found. This is proven at Homer, where two sands 700 feet apart produce oil of the same gravity and quality. An open fault of more than 200 feet displacement through the center of the structure forms the avenue for the vertical migration of the oil. The vertical migration through faults and crevices is likewise accompanied by lateral migration into the sands or reservoirs in which the oil is found. The nature of the fissures and the extent of the lateral migration explains the various differences in the quality of the oils.

Gas will move more freely than oil in faulted structures and perhaps some of the gas in some structures has passed off through the fissures and been lost. In the unfaulted structures, as Elm Grove, and Monroe, gas has slowly penetrated the unconsolidated sediments of the Coastal Plains area from its origin. The more volatile hydrocarbons move upward through the rocks until they find a porous reservoir with a tight cap to hold them in place; when the reservoir has been filled the overflow passes upward until it is confined in another trap. Gas having traveled through the rocks would naturally leave behind its heavier constituents.

In the Elm Grove gas field the gas from the Woodbine sand, when the field was first opened, contained approximately 100

gallons of gasoline to the million cubic feet of gas. Gas from the Nacatoch sand in the same field, in its further migration, lost all of its gasoline content.

In the Monroe gas field there is a triple dome instead of a single dome. Here we find a somewhat different condition. The gas in the highest dome was devoid of gasoline content when the field was opened. The gas from the center dome contained about 100 gallons of gasoline to the million cubic feet of gas, while in the lowest or southeast dome the gasoline content was about 400 gallons to the million cubic feet of gas. Thus is seen the effect of lateral migration from one part of the structure to another.

ElDorado, like the north Louisiana fields, is located on an uplift which is a distinct unit and probably formed at the same time as the north Louisiana uplifts and separated from them by a deep synclinal trough not unlike those which separate the producing areas of north Louisiana.

The thinning of the geologic section and the corresponding nearness to the Pennsylvanian and older shales, together with the folding and faulting, have made possible the accumulation of oil and gas in the ElDorado Field.

K. C. Heald: It is extremely important to obtain fossil evidence to establish the identity of the various oil-yielding sands in the fields of northern Louisiana and southern Arkansas. For instance it is possible, and in my own mind seems probable, that the red beds in the Eldorado field which Mr. Crider has assigned to the Lower Cretaceous are actually a part of the Bingen formation which is also red. If these red beds are in the Bingen, the encouragement to deep exploration is infinitely greater than if they are a part of the Lower Cretacous.

Edward Bloesch: The map of the Monroe, La., field as compiled by the U. S. Bureau of Mines shows faults occurring in the southeast part of the field, where the gas is richer in gasoline. I wish to ask Mr. Crider if his observations are different from the ones of the Bureau of Mines.

A. F. Crider: Since the report by the Bureau of Mines was published, a very important well has been drilled near the center of the NE¼ of the NE¼ of Section 34, T. 19 S., R. 5 E., by the Atlas Oil Company. The top of the Monroe gas sand in this well was found at a depth of 2142 feet below sea level. The well showed about 500,000 cubic feet of gas. The results of this well eliminates the possibility of a northeast southwest fault and shows a general plunging anticline the lowest part of which is to the southeast where we would expect the highest gasoline content in the gas.

STRATIGRAPHY OF A PART OF SOUTHERN UTAH

RAYMOND C. MOORE[1]

INTRODUCTION

The occurrence of oil seepages and oil-saturated rocks in parts of southern Utah and the production of oil in small quantities in two southern Utah fields, one on San Juan River in the southeastern part of the state, the other near Virgin City in the southwestern corner of the state, has for some time attracted the attention of geologists and oil operators to the possibility of commercial production in this region. A further incentive has been the known existence of large anticlines and domal structures in east central and southern Utah and the probable existence of smaller structures of favorable character in which possible petroliferous formations are involved. The chief deterrent feature in the rapid exploration and testing of this country has been its inaccessibility and the very large cost of drilling. Exploratory work is, however, proceeding and will doubtless continue until the geological conditions and possibilities of oil production are fairly definitely known. Because of an intrinsic geologic interest which attaches to this classic region where early workers developed some of the fundamental concepts in geologic science, but particularly on account of its importance to the petroleum geologist who is concerned with the problems of this and adjoining regions, this brief summary of stratigraphic observations based on detailed and reconnaissance field work during the summer of 1921 is presented.[2]

The area examined by the writer lies in central southern Utah in Kane, Garfield and Wayne counties. Kane County borders the Arizona state line; each of the counties is bounded on the east by the deep, practically impassable canyon of Colorado River and extends westward from this stream a distance of some eighty to ninety miles. Studies in southern Utah were supplemented by reconnaissance examination on a trip south-

[1]Published by permission of the Director, U. S. Geological Survey.

[2]The writer wishes to acknowledge valuable assistance by Messrs. A. C. Tester and P. C. Benedict.

ward from Kanab to the north brink of the Grand Canyon at Bright Angel Point.

Southern Utah is not reached by any railroad. Travel pro-

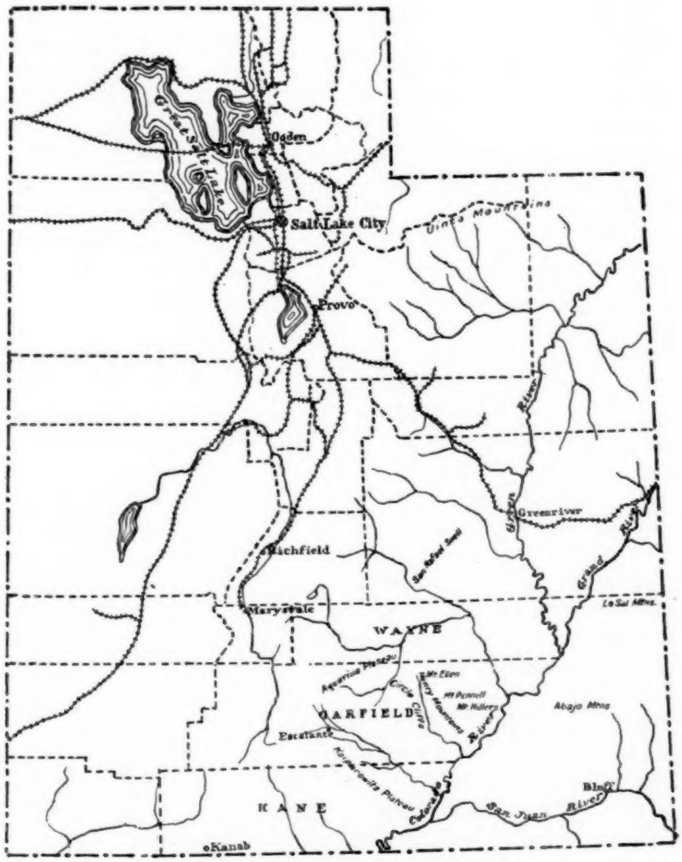

Fig. 1. Index Map of Utah.

ceeds by auto or wagon roads from the nearest convenient railway point to all settlements, some of them nearly 200 miles distant, but there is very much of the country which is not

reached by a road of any sort, where travel if possible at all must be by horse and pack-train. The rail-head of the central Utah Branch of the D. & R. G., at Marysvale is the point of

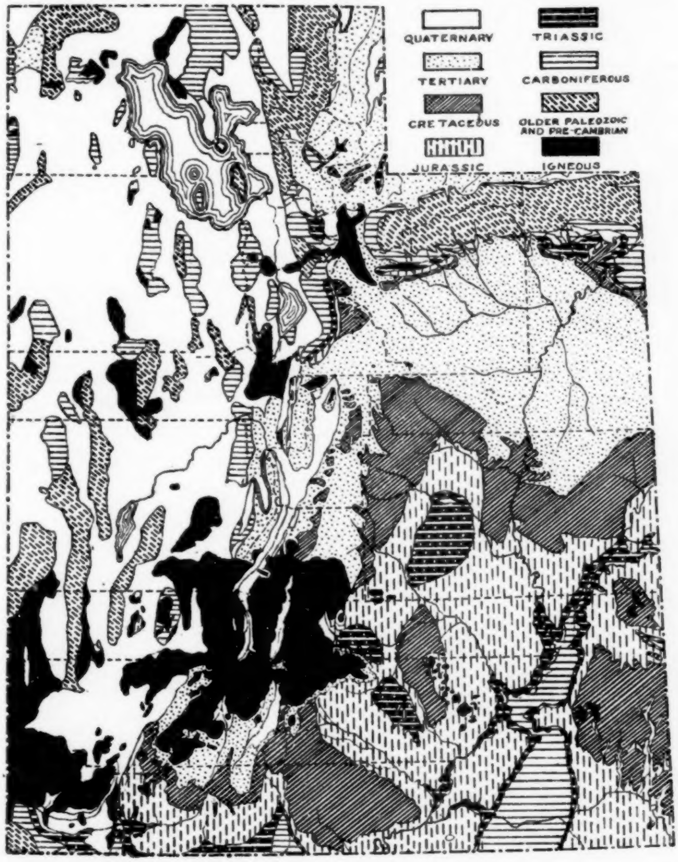

Fig. 2. Sketch geological map of Utah.

departure for Panguitch, Kanab and the western part of Kane, and Garfield counties. The eastern part of these two counties and all of Wayne County is more easily reached from Richfield or from Greenriver.

All of those striking features of desert or semi-desert plateau and canyon topography for which the Colorado Plateau region is famous are found in the portion of the province here under consideration—indeed, some of them are probably better developed in this district than anywhere else. The lofty, extensively lava-capped High Plateaus, much of whose surface stands more than 10,000 feet above the sea, here approach most nearly the deeply carved gorge of the great master stream of the southwest, the Colorado. Successive plateaus or great escarpments, each bounded by precipitous cliffs, lead like giant steps from the heights to the canyon depths. Erosion by running water has carved innumberable vertical-walled and impassable canyons. Laborious travel follows circuitous routes along the bottoms of these, mostly dry-floored canyons and across the shoulders of mountainous mesas. The southeasternmost of the High Plateaus is the Aquarius; a prominent south-projecting promontory almost cut off by erosion from the main body of the Aquarius is known as Table Cliff Plateau; farther west and extending southward into Kane County is Paunsagunt Plateau. The precipitous walls bounding these plateaus expose in many places the pink Tertiary formations of which they are composed and have come to be known as the Pink Cliffs. Southeastward from Table Cliff Plateau and nearly 3000 feet below it, Kaiparowits Plateau, upheld by strong Cretaceous sandstones, reaches some sixty miles, stopping short opposite Navajo Mountain at the canyon of the Colorado. The northeast face of the Kaiparowits is a high, nearly unbroken straight cliff and is appropriately designated the Straight Cliffs. The Escalante basin, an intricately dissected canyon area, lies below the Straight Cliffs, and beyond it to the northeast are the Circle Cliffs, a wall of nearly vertical cliffs which surround an elongate elliptical area trending northwest and southeast. On the east side of the Circle Cliffs are long, prominent hogback ridges formed by massive,uptilted sandstones which compose part of the Water Pocket fold. South of the Pink Cliffs in western Kane County are great south-facing cliffs, one composed of white sandstone, the White Cliffs, and another composed of red sandstone, the Vermilion Cliffs. In eastern Garfield County a variation in the characteristic topography is in-

troduced by several peaks composed of igneous rock, one of which rises to more than 11,400 feet. These, the Henry Mountains, are laccolithic in origin and the sedimentary rocks are upturned about them. The igneous rocks have been carved into alpine peaks, ridges and valleys, and in places there are great talus piles of angular rock fragments. The topographic features of southeastern Utah, extending northward to the San Rafael Swell, a feature closely resembling the Circle Cliffs, are shown in the sketch, Figure 3.

Colorado River, which is formed by the junction of the Grand and the Green at the east border of Wayne County, flows in an extremely irregular course southwestward, and to it all other streams in the region are tributary. The most important of these are, on the north, Fremont and Escalante rivers, and on the south, San Juan River, all perennial. Smaller streams, excepting only those of the high lands which are fed by melting snows and springs, are intermittent but at times of rain become muddy torrents. For the use of man, including the drilling of wells, dependence must be had on widely scattered small springs or seeps, and "tanks", naturally excavated hollows in sandstone or stream-bed in which rain water may accumulate. In drilling a test well in the Circle Cliffs it was necessary to haul all the water from 12 to 16 miles. Artificially constructed tanks may impound water if the local showers of the summer months chance to favor the locality selected. In the event of discovery of oil in commercial quantities in almost any part of southern Utah it would be possible to provide for water supply.

SEDIMENTARY ROCKS

The rock formations which appear at the surface in central southern Utah range in geologic age from Permian to Tertiary. In regions not far distant older rocks, Pennsylvanian to Pre-Cambrian, appear. A test well recently drilled by the Ohio Oil Company in the Circle Cliffs penetrated 3212 feet of Permian and older rocks. Description of these formations and discussion of their correlation may be divided into two parts, those which are exposed in the area under consideration, and those which do not here appear at the surface. The following tabu-

lar statement shows all of the stratigraphic divisions which are recognized:

Table of Formations

System	Formation	Description of strata	Thickness in feet
Tertiary	Wasatch	Limestone, calcareous sandstone, and shale, pink, white, and vari-colored, evenly stratified, rather soft. Outcrops in cliffs and forms slopes; composes the highest plateaus.	2000+
Cretaceous	"Laramie" sandstone	Sandstone, yellowish gray, massive to medium bedded, with some sandy shale, a prominent cliff-forming division. Grades without break into formation below.	250–400
	Lewis shale	Shale, gray to drab, sandy containing some thin beds of yellow sandstone.	500 1200+
	Mesaverde sandstone	Sandstone, yellow to brown, irregularly bedded, medium to massive, Contains lignite beds up to 4 feet in thickness. Forms prominent escarpment.	300–1000
	Mancos shale	Shale, bluish drab, argillaceous to sandy, very uniform in color and texture. Forms slopes and badlands. Thickness 1100–1200 feet.	
		Sandstone, yellowish, medium to massive, irregularly bedded. Forms mesas and hogbacks near Henry Mtns. Thickness 60–100 feet.	
		Shale, bluish drab, sandy, grading to fossiliferous sandstone at base. Shale contains abundant *Gryphaea newberryi* and other fossils. Thickness 900–1000 feet.	2200
	Dakota sandstone	Sandstone, yellowish to nearly white, in part conglomeratic, irregularly bedded, locally contains lignite.	0 100
	McElmo formation	Shale, maroon to light bluish gray, sandy, banded. Conglomerate and coarse gritty sandstone, maroon, yellow and gray, irregularly bedded. Forms escarpments and hogbacks.	197–565
Jurassic	"Upper Jurassic sandstone"	Sandstone and shale, thinbedded, maroon. Sandstone, very massive and very soft, generally white or light cream colored at top, middle and lower portions orange brown. Grades irregularly into very sandy, crossbedded shale Weathers readily forming abundant dune sand	973–1430
	"Gypsiferous zone"	Shale, pink to red, containing gypsum in beds up to 5 feet thick, and a few beds of white massive sandstone.	
		Shale, sandstone and siliceous limestone, dark maroon and light bluish green, forms distinct scarpement.	100–450?
	Navajo sandstone	Sandstone, light creamy yellow, white and pinkish, highly crossbedded, very massive, coarse grained, calcareous. Weathers in high cliffs, and in innumerable cones and towers.	1260–1400

System	Formation	Description of strata	Thickness in feet
Jurassic	Todilto formation	Sandstone, chiefly maroon, locally conglomeratic and coarse grained, thin- and extensively cross-bedded. Locally contains maroon sandy shale and thin, hard, bluish limestone.	125-215
	Wingate sandstone	Sandstone, mostly vermilion red to reddish brown, very massive, prominently jointed, outcropping commonly in a single vertical cliff resembling a palisade. Cross-bedded, but not prominently as in Navajo.	250-400
Triassic	Chinle formation	Shale and limestone, light bluish and lavender, the shale very calcareous and grading irregularly into hard, uneven, dense, mottled limestone. Locally near top a limestone conglomerate appears.	185-200
		Shale and sandstone, the shale varicolored, generally darker than division above but brilliant, sandy; the sandstone thin to massive, crossbedded. Contains much silicified wood appearing partly in great logs.	285-305
	Shinarump sandstone	Sandstone, light gray to yellowish, coarse grained to conglomeratic, very irregularly bedded and variable in thickness. Grades locally into bluish sandy shale. Contains silicified wood. Forms prominent bench.	10-125
	Moenkopi formation	Shale and sandstone, chocolate brown to yellowish, containing locally in upper portion very thin hard limestone beds. The shale very sandy and grading into shaly sandstone; the sandstone varying from thin-bedded, platy to thick, massive beds, in part saturated with petroleum.	304-480
Permian	Kaibab limestone	Limestone, white to yellowish, massive, more or less dolomitic, in part cherty, one widely distributed bed containing abundant angular fragments of chert. Lower part increasingly sandy and containing some beds of calcareous sandstone. Fossiliferous in part containing numerous brachiopods, bryozoans, etc.	125-165
	Coconino sandstone Supai (?) formation	Sandstone, white massive, saccharoidal, calcareous. Upper part exposed in canyons in central part of Circle Cliffs; penetrated by Ohio Oil Company well in Circle Cliffs but not differentiated from subjacent division. Sandstone, white to yellow, massive, containing some red material, a little shale and thin limestone. Penetrated by Ohio Oil Company well.	1630 (?)
Pennsylvanian	Goodridge (?) formation	Limestone, white, hard massive, with interbedded sandstone, white, gray and red, and some red shale. Penetrated by Ohio Oil Company well.	1552 (?)

ROCKS NOT EXPOSED

Information concerning the older rocks which in the portion of southern Utah under consideration do not appear at the surface is obtainable from the record of deep borings, and less

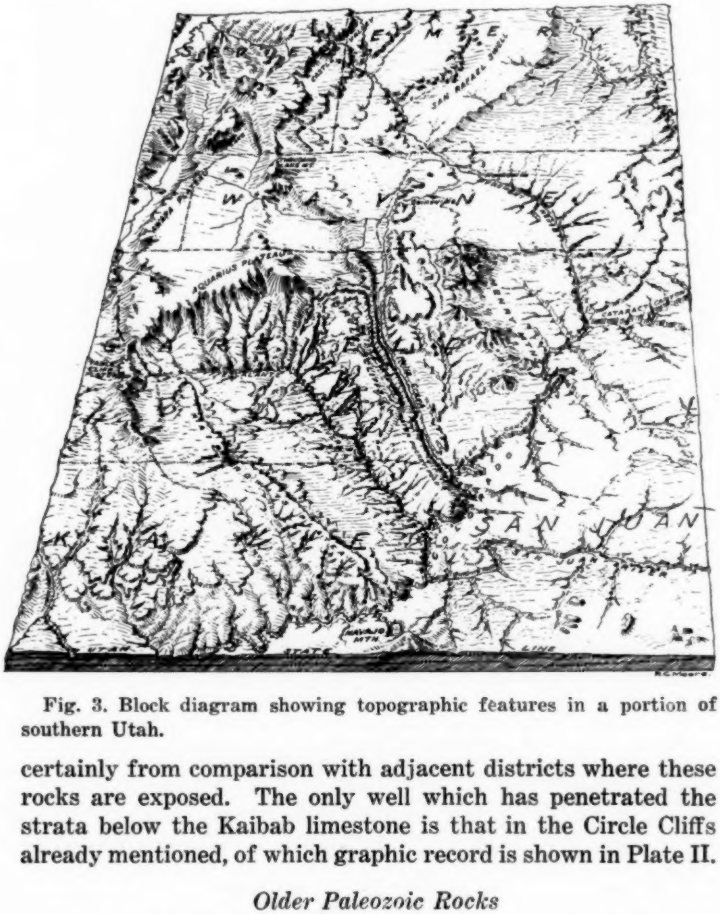

Fig. 3. Block diagram showing topographic features in a portion of southern Utah.

certainly from comparison with adjacent districts where these rocks are exposed. The only well which has penetrated the strata below the Kaibab limestone is that in the Circle Cliffs already mentioned, of which graphic record is shown in Plate II.

Older Paleozoic Rocks

It is possible that formations of Cambrian age underlie central southern Utah inasmuch as rocks belonging to this period

are extensively developed farther north in Utah, in the Grand Canyon region to the southwest and, less importantly, in southwestern Colorado. Ordovician and Silurian rocks are reported from northern and western Utah but do not occur in the Grand Canyon or in southwestern Colorado. Devonian limestone is found in the Grand Canyon section (up to 100 feet), in southwestern Colorado (Ouray limestone, 100-250 feet, partly Mississippian), and in northern Utah, and rocks of this age very possibly occur beneath central southern Utah. Older Paleozoic rocks have nowhere been recognized in borings in this region.

Carboniferous and Permian

The Mississippian appears to be very widely distributed in the west, being represented generally by very dense, massive, rather unfossiliferous limestones. In the Grand Canyon Mississippian fossils have been reported[2] from the lower part of the Redwall limestone which has a thickness of 600 to 700 feet in the canyon district, thickening to the west. In southwestern Colorado the upper part of the Ouray limestone, lithologically similar to the Redwall, contains Mississippian fossils. In central northern Utah and elsewhere to the north is a widely distributed massive, dense limestone ("Wasatch", Madison, etc.) in which sparse lower Carboniferous fossils have been obtained. It is possible, as suggested by Girty,[3] that part of the lowermost beds exposed in the San Juan canyon at Goodridge may be Mississippian, though it is more probable that if rocks of this age are present they do not appear at the surface. Mississippian strata may be anticipated at depths beneath the surface in southern Utah.

Abundantly fossiliferous rocks of Pennsylvanian age (Goodridge formation) are known in the canyon of San Juan River west of Bluff (1350 feet exposed[4]) which are equivalent at least in large part to the Hermosa formation (1600-2000 feet) of southwestern Colorado. Corresponding beds appear at the surface in Cataract Canyon below the junction of the Grand

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[2] Noble, L. F., The Shinumo Quadrangle, Grand Canyon district, Arizona. U. S. Geol. Survey, Bull. 549, 1914.

[3] Girty, G. H., in Woodruff's report on the Geology of the San Juan oil field. U. S. Geol. Survey, Bull. 471, 1912.

[4] Measurement by the writer.

and the Green. Pennsylvanian fossils are reported[5] from the upper part of the Redwall limestone in the Grand Canyon region, and recently Reeside and Bassler[6] have reported fossils identified by Girty as types belonging to Pennsylvanian or Permian which come from an horizon approximately 1000 feet below the top of the Redwall in southwestern Utah. These Pennsylvanian beds consist for the most part of alternating limestones, sandstones and minor amounts of shale. While it is uncertain how much of the Redwall is Mississippian and how much Pennsylvanian, and similarly how great thicknesses of these divisions may underlie central southern Utah, it is extremely probable that Carboniferous beds corresponding to these are present. The test in the Circle Cliffs encountered several hundred feet of limestones and sandstones, including some red rocks, in the lower part of the well. These strata in all probability represent the Carboniferous, but whether only a part of the Goodridge or all of the Goodridge and some lower beds is not known. The top of the Pennsylvanian is tentatively placed at the top of the limestone encountered at a depth of 1630 feet.

The Circle Cliffs well found white, yellow and brown sandstone with some red material and a little lime between the Kaibab limestone at the surface and the top of the limestone which may be considered as possibly Goodridge. This interval corresponds stratigraphically to that of the Coconino sandstone and Supai formation of the Grand Canyon section. Schuchert[7] has pointed out the occurrence of an unconformity in the Supai beds of the Grand Canyon section which divides a predominantly shale zone above from a sandy one below. Noble[8] proposes to introduce a new name (Hermit shale) for the beds above the unconformity and to restrict the name Supai to the beds below it.

Since the rocks below the Kaibab in the Circle Cliffs well

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[5]Noble, L. F., loc. cit.

[6]Reeside, J. B., Jr., and Bassler, H., Stratigraphic sections from southwestern Utah, U. S. Geol. Survey, Prof. Paper, 129D, 1922.

[7]Schuchert, Chas., On the Carboniferous of the Grand Canyon of Arizona, Am. Jour. Sci., 4 ser., vol. 45, p. 356, 1918.

[8]Noble, L. F., Paleozoic formations of the Grand Canyon at Bass Trail, U. S. Geol. Survey, Prof. Paper, 131B (in press).

appear to consist mainly of sandstone it is not possible from evidence at hand to discriminate between the Coconino sandstone and the subjacent division, and because it is not known whether this lower division corresponds to the Supai as re-

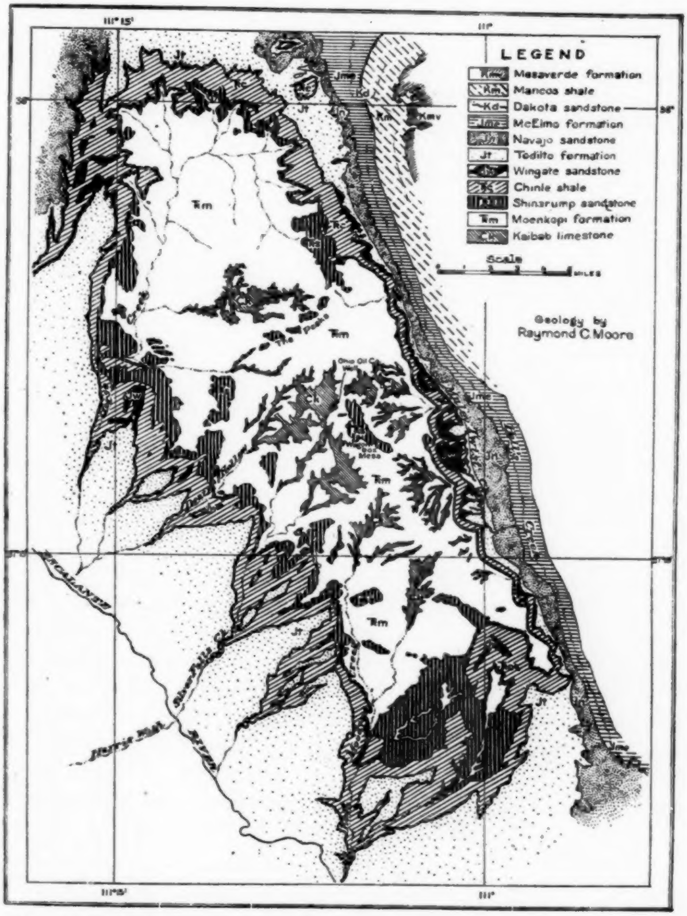

Fig. 4. Geological map of the Circle Cliffs, Garfield County, Utah. (Note: Upper Jurassic sandstone and shale, and gypsiferous zone included with McElmo formation).

stricted by Noble or to the other rocks as well, the strata below the Coconino may be designated as Supai(?).

ROCKS EXPOSED

Permian. The Kaibab limestone, with typical lithological and fossil characters, appears in the central part of the Circle Cliffs, its thickness ranging from about 125 to 160 feet. It consists of yellow to white, dolomitic, in part very cherty, and in part very sandy limestone, the subdivisions of which are fairly constant and easily recognizable in different exposures. It grades downward without sharp line of division into white sugary sandstone which on account of lithologic resemblance and similar stratigraphic position may be identified as the Coconino sandstone. Outcrops of the Kaibab shown on the sketch geological map of the Circle Cliffs, Plate I, include undifferentiated Coconino. The upper surface of the Kaibab is uneven, and in places the upper members are missing. It is clear that erosion intervened before deposition of the Moenkopi. The Kaibab is referred to the Permian because examination of its fauna shows that while productids and other shells representing types common in the Pennsylvanian are present, elements which are distinctively Pennsylvanian are lacking; also because fossils which are identified as Permian have been found in the Grand Canyon region in strata below the Coconino[9]. The fauna of the Kaibab, determined from collections in the Grand Canyon region[10] and southwestern Utah[11] contains a considerable number of species among which Girty[12] distinguishes two facies corresponding to different stratigraphic horizons: an upper, consisting chiefly of mollusks which represents the "Bellerophon limestone" of older geologists and a lower, the normal Kaibab fauna, characterized by a number of brachiopods, corresponding to the fauna which occurs in the San Andreas limestone of the Permian Manzano group in New Mexico. Fossils collected in the Circle Cliffs represent the normal Kaibab rather than the "Beller-

[9]Noble, L. F., loc. cit.

[10]Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Arizona, U. S. Geol. Survey, Bull. 549, 1914.

[11]Reeside, J. B., Jr., and Bassler, H., Stratigraphic sections in southwestern Utah, U. S. Geol. Survey, Prof. Paper 129D, 1922.

[12]Girty, G. H., in Reeside and Bassler, loc. cit.

ophon limestone" fauna. An earlier view which referred the Kaibab and underlying Coconino and Supai formations to the Pennsylvanian is now generally modified in the light of accumulating evidence to include the two upper and at least part of the lower in the Permian.

The Kaibab is not recognized in the San Rafael Swell[13], in Cataract Canyon[14], or in the San Juan oil field[15], and it thus appears that the exposures in the Circle Cliffs represent the northeasternmost known extent of the normal type of this formation. The Kaibab is not to be correlated with the Goodridge formation of the San Juan oil field, as suggested by Gregory[16], for the Goodridge has a very typical Pennsylvanian fauna with practically nothing, paleontologically, in common with the Kaibab, and it now appears that beds overlying the Goodridge are equivalent to the Coconino and Supai (?) which underlie the Kaibab. While the Kaibab cannot be traced northward or eastward it is widely distributed and is increasingly thick southwestward. In the Grand Canyon region it reaches a thickness of at least 600 feet[17], and in southwestern Utah nearly 1000 feet.[18] (See Plate I.) The Kaibab may be correlated with the San Andreas limestone in New Mexico and is probably equivalent at least in part to the fossiliferous Permian limestones (Park City) on the flanks of the Uinta Mountains, where the stratigraphic succession is almost identical with that of southern Utah and where is developed the "Bellerophon limestone" fauna recognized in the upper part of the Kaibab to the southwest.

Triassic. To the Triassic are referred three formations, the Moenkopi, Shinarump and Chinle. Excepting the Shinarump these are composed of non-resistant rocks which yield readily to weathering and erosion. They are also distinguished

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[13]Emery, W. B., The Green River Desert section, Utah, Am. Jour, Sci., 4 ser., vol. 46, p. 555, 1918.

[14]Paige, Sidney, Personal communication.

[15]Woodruff, E. G., Geology of the San Juan oil field, Utah, U. S. Geol. Survey, Bull. 471, p. 76, 1912. Also personal observation.

[16]Gregory, H. E., Geology of the Navajo country, U. S. Geol. Survey, Prof. Paper 93, p. 22, 1917.

[17]Noble, L. F., loc. cit., pl. 9.

[18]Bassler, Harvey, andReesi de, J. B., Jr., Oil prospects in Washington County, Utah, U. S. Geol. Survey, Bull. 726, p. 92, 1921.

by brilliant colors arranged in persistent alternating bands.

The Moenkopi conists almost entirely of sandstone and sandy shale, chocolate brown and yellow in color. The sandstones are in part hard and massive but are more generally thin-bedded to shaly and rather soft. The harder strata cap buttes and mesas or form projecting ledges; the softer beds weather in gentle slopes. The Moenkopi unconformably over-lies the Kaibab and is unconformably succeeded by the Shinarump. Its thickness in the Circle Cliffs ranges from a trifle over 300 feet to nearly 500 feet, variations in thickness being mainly due to pre-Shinarump erosion. In places the irregularities at the top of the Moenkopi are very evident. A sandstone which ranges in thickness up to 50 feet and which is highly impregnated with oil occurs in the upper part of the Moenkopi. No fossils were found in the Moenkopi in the Circle Cliffs region but elsewhere numerous marine Lower Tri-

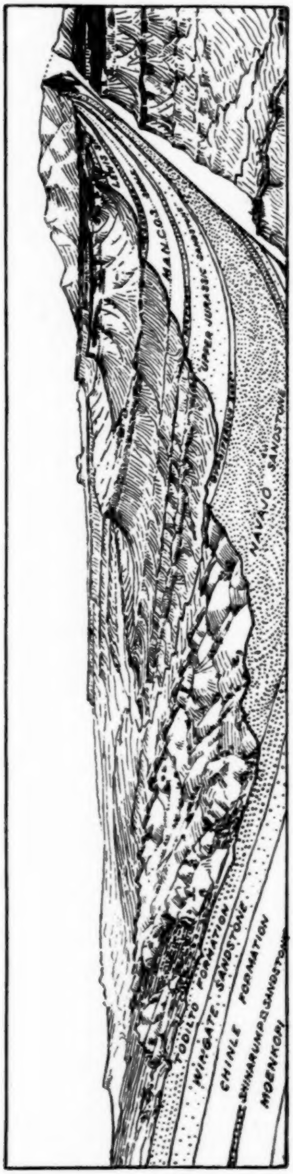

Fig. 5. Diagrammatic sketch showing Jurassic and Cretaceous formations west of the Henry Mountains. View looking east from top of Water Pockets fold toward Mt. Ellen, a laccolithic intrusion of igneous rock. A portion of the rocks have been removed to show the rock formations and structure.

assic fossils have been found in it, which correspond to the *Meekoceras* beds of south-eastern Idaho.[19]

The Moenkopi formation is widely distributed in the Colorado Plateau region, in general thinning to the east and increasing in thickness to the west. In northeastern Utah the Moenkopi probably corresponds to fossil-bearing red beds containing the *Meekoceras* fauna, Woodside, Thaynes and Ankareh[20]. In the San Juan oil field Woodruff[21] describes 1640 feet of red shales and sandstones overlying the Goodridge as Moenkopi (see Plate II); Gregory[22] identifies only 500 feet here, excluding 845 feet of strata which were included by Wooduff; but Miser[23] in recent careful studies along the canyon of San Juan River has differentiated the beds above the Goodridge to include, in ascending order; Supai (?) formation, 380 feet; Coconino sandstone, 400-600 feet; Moenkopi formation 830-855 feet, including in middle portion De Chelly (?) sandstone, 0-90 feet; Shinarump; Chinle; Wingate etc. The sandstone indentified as Coconino by Miser thickens to the northwest and north and appears to correspond to the very thick sandstone division which underlies the Kaibab in the Circle Cliffs, and the massive "Aubrey" sandstone in Cataract Canyon. The Moenkopi of the San Juan, as described by Miser is considerably thicker than in the Circle Cliffs, but farther southeast it is much thinner. In southwestern Colorado the Cutler formation may represent the Moenkopi. North of the Grand Canyon, in southwestern Utah[24] and south-

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[19]Dr. G. H. Girty reports identifications of Moenkopi fossils from southwestern Utah and discusses the correlation of the fauna in Reeside and Bassler's paper on southwestern Utah. (U. S. Geol. Survey, Prof. Paper 129D). "There is scarcely room for reasonable doubt that Walcott's 'Permian' of the Kanab Canyon section, which is Moenkopi, is the same as the 'Permo-Carboniferous' of the Wasatch Mountains, and that the 'Permo-Carboniferous' of the Wasatch Mountains is the same as the well known Lower Triassic of Idaho."

[20]Boutwell, J. M., Geology and ore deposits of the Park City district, Utah, U. S. Geol. Survey, Prof. Paper 77, 1912; see also Girty, G. H., The fauna of the Phosphate beds of the Park City formation in Idaho, Wyoming and Utah, U. S. Geol. Survey, Bull. 436, p. 8, 1910.

[21]Woodruff, E. G., loc. cit.

[22]Gregory, H. E., loc. cit., p. 29.

[23]Miser, H. D., Unpublished data.

[24]Reeside and Bassler, loc. cit.

eastern Nevada[25] the Moenkopi is well developed, reaching a thickness of 2000 feet.

The Shinarump sandstone consists mainly of coarse, light colored sandstone which is locally conglomeratic and which grades in places to bluish sandy shale. It is extremely irregular in bedding and variable in thickness. The average thickness in the Circle Cliffs is about 50 feet, but measurements of less than 10 feet and of more than 125 feet are noted. The Shinarump sandstone is much more resistant than the adjoining formations and its outcrop forms prominent benches and small mesas (see geologic map. Fig. 4.) Fragments of silicified wood occur in this formation but are less common than to the south where the rock is coarser. Fossil plants were collected in the Circle Cliffs. Its fossils and stratigraphic relations indicate without question the Triassic age of the Shinarump. Within the Plateau province the persistent lithologic and associated stratigraphic features belonging to the Shinarump formation make it very widely and easily recognizable, but beyond the borders of the province it has not been identified.

The Chinle formation, which appears to grade normally upward from the Shinarump, is a relatively non-resistant division which outcrops in the slopes beneath the Wingate sandstone cliffs. It is commonly stripped for some distance back from the edge of the Shinarump escarpment below it. Two rather distinct members may be distinguished in the Circle Cliffs, a lower, consisting of dark, in part brilliantly colored sandy shales and irregularly bedded sandstones, and an upper, consisting mainly of hard, uneven, irregularly mottled light colored, dense limestone and calcareous shale. The lower division is commonly somewhat thicker than the upper, the total thickness of the formation in the Circle Cliffs ranging from 450 to 500 feet. The lower strata contain considerable petrified wood and in a few places large logs ranging up to 75 feet in length. Fossil invertebrates, not yet identified, were found also in the lower part of the formation. Else-

[25]Longwell, C. R., Geology of the Muddy Mountains, Nevada, with a section to the Grand Wash Cliffs in western Arizona, Am. J. Sci., 4 ser. vol. 50, pp. 39-52, 1921.

where[26] remains of a number of Upper Triassic vertebrates have been discovered in the Chinle. Deposits equivalent to the Chinle or known by that name are very widely distributed in the Colorado Plateau region, and indeed, extend far beyond its borders. The thickness of the Chinle in the Circle Cliffs region is considerably less than to the southeast (San Juan oil field, 1332 feet; Navajo country, 1200 feet) or southwest (Washington County, Utah, 1000 feet; Muddy Mountains, southeastern Nevada[27], 800-3200 feet). In southwestern Colorado the Dolores formation which corresponds to the Chinle has a thickness of about 1000 feet in some places[28] but elsewhere is much thinner (Rico district, 400 feet, Ouray quadrangle, 100 feet) and locally disappears entirely[29], these variations being due to pre-La Plata erosion.

Jurassic. The Jurassic period is represented in southern Utah mainly by a series of great sandstones which in distinctive lithologic character and prominent topographic expression form one of the most striking elements in the make-up of the region. The combined average thickness of these sandstones is about 2000 feet. At least five subdivisions are readily distinguished in eastern Kane, Garfield and Wayne counties, some of which at least, are traceable over thousands of square miles in adjacent territory. In ascending order these subdivisions are: (1) Wingate sandstone, (2) Todilto formation, (3) Navajo sandstone, (4) "Gypsiferous zone," and (5) "Upper Jurassic sandstone." The lower three comprise the La Plata group as described in the Navajo country[30] the upper two were included by Lupton[31] in the McElmo formation. No important stratigraphic breaks have been identified

[26]Gregory, H. E., loc. cit., gives summary, pp. 46-7.

[27]Longwell, C. R., The Muddy Mountain Overthrust in Nevada, Jour. Geol., vol. 30, p. 66, 1922.

[28]Cross, Whitman, and Home, Ernest, Red Beds of southwestern Colorado and their correlation, Geol. Soc. Am., Bull., vol. 16, p. 473.

[29]Personal observations, Rio Piedra, near Pagosa Springs, Colorado. See also, Cross, Whitman, and Larsen, E. S., Contributions to the stratigraphy of southwestern Colorado, U. S. Geol. Survey, Prof. Paper 90, p. 45, 1914.

[30]Gregory, H. E., loc. cit.

[31]Lupton, C. T., Oil and gas near Green River, Grand County, Utah, U. S. Geol. Survey, Bull. 541, p. 124, 1914; Geology and coal resources of Castle Valley, Utah, U. S. Geol. Survey, Bull. 628, p. 23, 1916.

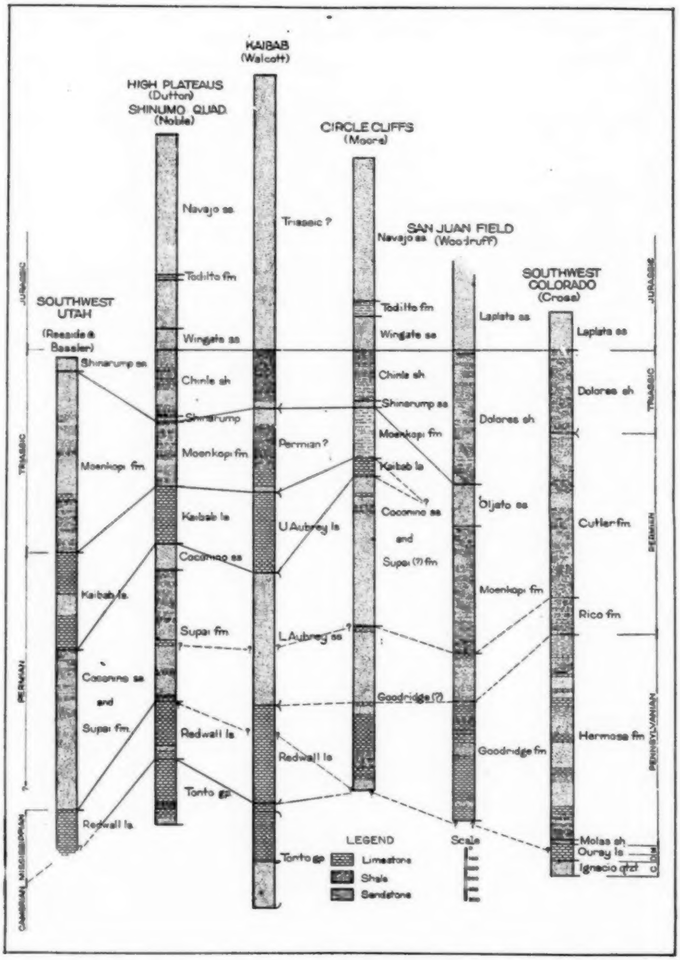

Plate I. Correlation of the Circle Cliffs section with adjoining regions.

within the Jurassic of southern Utah but it may be noted that while deposits of this age are chiefly non-marine, a portion contains a marine invertebrate fauna.

The Wingate sandstone is a resistant, very massive formation, for the most part brownish red in color, which outcrops as a single ledge with average thickness in the Circle Cliffs of about 300 feet. It is intersected by prominent joints which largely control weathering and produce the clean-cut palisade-like walls which characteristically mark the Wingate outcrop and which compose the cliffs of Circle Cliffs. Angular blocks of the sandstone strew the slopes of the Chinle. The Wingate is cross-bedded but because of uniformity of coloring and degree of cementation this feature is not prominent, as in the Navajo. Irregularities at the contact with the Chinle, the presence locally of conglomeratic strata at the base of the Wingate and of deep, sand-fifilled mud cracks at the summit of the Chinle[32] indicate a break preceding the Wingate. There is no indication here of an important interval of erosion but as has been noted the pre-La Plata strata were at least locally deformed and beveled by erosion before deposition of the Jurassic sandstones. The Wingate is widely exposed in the Circle Cliffs (Fig. 4), in the Miners Mountain dome in Wayne County, in the San Rafael Swell and along portions of the canyons of Green, Grand and Colorado rivers in eastern Utah. As pointed out by Dake[33] the Wingate of Emery[34] in the San Rafael Swell includes in addition to the Wingate as described here, the Todilto and the Navajo. The Wingate comprises the lower part of the sandstones which form Comb Ridge east of the San Juan oil field; it is very extensively distributed in the Navajo country, northeastern Arizona, and in western New Mexico; it forms the Vermilion Cliffs in southern Kane County, Utah, and continues westward into Washington County, where, although retaining characteristic features, it cannot be differentiated precisely from the superjacent sandstone.

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[32]Gilbert, G. K., Geology of the Henry Mountains, U. S. Geog. and Geol. Survey of the Rocky Mtn. Region, p. 9, 1977.

[33]Dake, C. L., The horizon of the marine Jurassic in central Utah, Jour. Geol. vol. 27, 1920.

[34]Emery, W. B., loc. cit.

The Todilto formation consists of thin and irregularly cross-bedded sandstone, conglomerate, sandy shale and locally in minor amount, of dense, blue limestone. The color is commonly dark red or maroon. The average thickness of the formation in the Circle Cliffs is about 175 feet. Striking contrast in physical characters, especially bedding, color and composition, and prominent topographic expression, makes very easy the differentiation of the Todilto formation. It was traced without finding essential change through eastern Kane, Garfield and Wayne counties; it was observed at many points in the canyons of Colorado and San Juan rivers[35]; and it is widely distributed in the Navajo country. The Todilto is perhaps represented by a thin-bedded, calcareous division noted by Cross[36] in the La Plata sandstone of southwestern Colorado, but southwest of the Circle Cliffs it gradually becomes indistinct.

The Navajo sandstone, largest single division of the Jurassic in southern Utah, is a thick, remarkably cross-bedded, massive formation of uniform character which is very widely distributed in the Colorado Plateau province. It is light-colored, mostly white to light creamy yellow but in places contains parts which are light orange red. The sand is rather loosely cemented. Weathering commonly etches the cross-bedding so that, aided in places by differences in coloring, it is very prominent; erosion, partly controlled by cross-bedding, develops forms which may be associated with the Navajo as characteristic, rounded domes, mosque-like towers, wigwams and irregular shapes. Caves and in places great natural bridges appear. In the Glen Canyon of Colorado River and in the White Cliffs of western Kane County, the Navajo outcrops in sheer, nearly vertical cliffs several hundreds of feet high. The thickness of the Navajo in eastern Garfield County is about 1300 feet; toward southwestern Utah it increases somewhat.

The Navajo is succeeded by red and light blue sandy shale, hard, evenly bedded siliceous limestone, sandstone and gyp-

[35]Longwell, C. R., Miser, H. D, and Paige, Sidney, Unpublished data.
[36]Cross, Whitman, Geology of the Rico quadrangle, U. S. Geol. Survey, Geol. atlas, folio 130, p. 5, 1905.

sum. Change in lithologic character is very marked but there is no certain evidence of unconformity. The strata of this zone have not been separately distinguished stratigraphically and may, pending further field studies, be designated conveniently as the "Gypsiferous zone." In this there are two subdivisions, somewhat different lithologically and distinctly expressed topographically. The lower of these is probably equivalent to the fossiliferous marine Jurassic described by Lupton[37] and Dake[38] a short distance farther north. The average thickness of this zone in Garfield County is 100 feet. The division was correlated with the Todilto by Emery[39] and was by Lupton[40] included in the McElmo formation. With the succeeding sandstone division this "Gypsiferous zone" is here tentatively excluded from the McElmo, which is a fresh water formation apparently equivalent to the Morrison formation of Cretaceous (?) age.

Massive, soft, cross-bedded, orange-brown sandstone, grading in places at the top to light creamy yellow or white, and changing somewhat irregularly in parts to sandy shale, is here designated as "Upper Jurassic sandstone." This soft sandstone division has a thickness of 975 to 1430 feet in the Water Pockets fold and northeast of Kaiparowits Plateau but it is largely concealed on account of the readiness with which it yields to the attack of weathering agencies. It follows the "Gypsiferous zone" without break and is designated as Jurassic only on the basis of its association with this horizon of known Jurassic age and its position below the McElmo which appears to overlie it uncomformably. This sandstone was erroneously called Navajo by Emery[41].

Cretaceous (?) The McElmo formation is here distinguished to include 200 to 600 feet of irregularly-bedded conglomerate, coarse grit, sandstone and banded sandy shale, red, maroon, light bluish and yellow-brown in color. The conglomerates occur at the base of the division and range in

[37]Lupton, C. T. Geology and coal resources of Castle Valley, Utah, U. S. Geol. Survey, Bull. 628, p. 24, 1916.
[38]Dake, C L., loc. cit.
[39]Emery, W. B., loc. cit.
[40]Lupton, C. T., loc. cit.
[41]Emery, W. B., loc. cit.

thickness up to 150 feet. In places they contain fragments of silicified wood and reptile bones. The occurrence of the conglomerate and unevenness in the surface on which it rests indicate an erosion break. Deposits corresponding to those here indicated are widely distributed in parts of the Plateau province but have not been studied in detail.

Cretaceous. The Cretaceous is represented in southern Utah by exposures in the vicinity of Henry Mountains, along the southern border of the High Plateaus in western Garfield and Kane counties, and in a southeastward projection of which Kaiparowits Plateau is the chief part, extending into eastern Kane County. The total thickness of the Cretaceous section is about 3500 feet. The rocks consist of alternating divisions of rather somber colored bluish drab shale and light yellowish brown sandstone, the former appearing in gully-scored slopes and badlands, and the latter in cliff-margined escarpments and hogbacks.

The lowest division, the Dakota sandstone, consists of light colored sandstone, conglomerate and sandy shale, and contains in places thin beds of lignite. It has a maximum thickness of a little more than 100 feet along the front of Kaiparowits Plateau where it forms a prominent bench, but along the Water Pockets fold west of the Henry Mountains it is much thinner, and in places is wanting. The Dakota appears unconformably to overlie the McElmo.

The Mancos shale consists mainly of bluish drab, argillaceous and in part sandy shale, containing in its middle portion a thin but rather persistent sandstone (Tununk sandstone member) 50 to 100 feet thick. The shale below this sandstone is 900 to 1000 feet thick, fossiliferous, contains great numbers of *Gryphaea newberryi* and other forms, and grades at the base into extremely fossiliferous brown sandstone. The shale above the middle sandstone is uniformly colored and textured shale which has a thickness of 1100 to 1200 feet. The total thickness of the Mancos in the vicinity of the Henry Mountains is about 2200 feet. In the face of Kaiparowits Plateau and southwest of Table Cliff Plateau the fossiliferous lower shale and basal sandstone are identical with exposures near the Henry Mountains, but in the latter

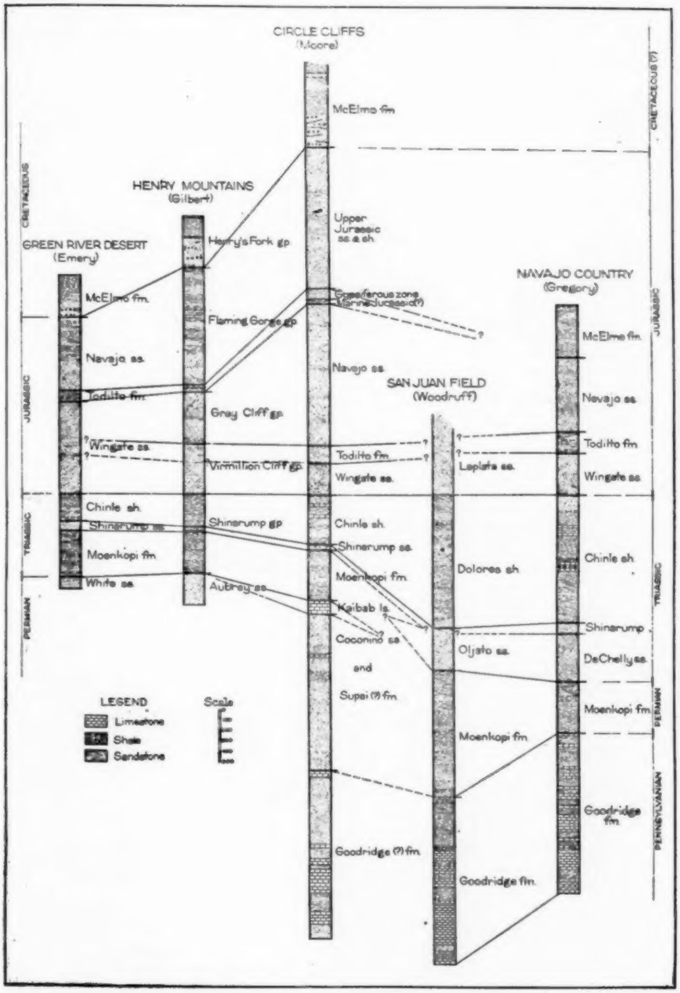

Plate II. Correlation of the Circle Cliff section with adjoining regions.

area no sandstone corresponding to the Tununk member is found. Near Table Cliff a measurement of 2100 feet of Mancos was obtained.

The Mancos shale is overlain with apparent conformity by irregularly bedded, massive, yellowish brown sandstone which in the vicinity of the Henry Mountains contains lignite in beds up to 4 feet thick. The thickness of this sandstone (Blue Gate sandstone of Gilbert[42]) is 300 to 400 feet near the Henry Mountains but in Kaiparowits Plateau and near Table Cliff Plateau its thickness increases to about 1000 feet. No fossils were obtained from the sandstone but, as noted by Lee[43], comparison with the Cretaceous sections of adjoining regions indicates that this formation is probably Mesaverde. It is extremely improbable that this sandstone could represent the Ferron sandstone of Castle Valley, some 50 miles to the north, as intimated by Lupton[44]. The Ferron occurs about 600 feet above the base of the Mancos and is overlain by 3000 feet of Mancos shale, while this sandstone is found 2200 feet above the base of the Mancos and, as seen in the Henry Mountains is succeeded by only a few hundred feet of shale.

The sandstone here designated as Mesaverde is overlain by sandy drab shale, somewhat lighter in color than the lower shales and having a brownish cast. Near the Henry Mountains this shale is 500 to 700 feet thick and contains in its upper part thin beds and lenses of sandstone. South of Table Cliff Plateau the thickness of this division is more than 1000 feet but measurement was not obtained. Based on comparison with the Cretaceous sections to the east this shale may be identified as the Lewis.

The Lewis shale, thus designating the division just described, is overlain conformably by massive yellowish gray sandstone which east of the Circle Cliffs appears in a prominent tableland bounded by high sheer cliffs. Its thickness is about 300 feet according to measurements made at its west

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[42]Gilbert, G. K., loc. cit., p. 4.

[43]Lee, W. T., Relation of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico, U. S. Geol. Survey, Prof. Paper 95, p. 50, 1915.

[44]Lupton, C. T., loc. cit., p. 32.

margin but Gilbert[45] reports a thickness of 500 feet. This sandstone (Masuk sandstone of Gilbert) probably represents the "Laramie" of southwestern Colorado which is apparently of Montana age[46].

Tertiary. In the Aquarius, Table Cliff, Paunsagunt and other of the High Plateaus may be found exposures of the youngest stratified rocks of the region, pink, lavendar, white and vari-colored limestones, sandstones and sandy shales of Eocene age. These rocks, which in Garfield and Kane counties have been referred to the Wasatch, appear in vertical cliffs and in fantastically carved, brilliantly tinted walls of canyons heading at the margin of the plateaus, such as the famous Bryce Canyon west of Tropic. The thickness of the Tertiary in this region is about 2000 feet. Much of it, especially to the north, is buried beneath a great accumulation of extrusive igneous rocks.

The Tertiary rests with profound unconformity on the subjacent rocks. Along the margin of Table Cliff Plateau appear at different places next beneath the Tertiary, "Laramie sandstone" (?), Lewis shale and Mesaverde sandstone. Eastward along the edge of Aquarius Plateau the Tertiary is successively in contact with the Mancos shale, Dakota sandstone, McElmo formation, "Upper Jurassic sandstone," "Gypsiferous zone" and finally the Navajo sandstone. An important deformative movement, regional in character, which produced such structural features as the Water Pocket fold and the Circle Cliffs dome, occurred following Cretaceous deposition. Before sedimentation in early Eocene time this deformed rock series had been planed off by erosion to a nearly level surface, a denudation involving the removal in places of rock strata some thousands of feet in thickness.

DISCUSSION

E. G. Woodruff: Mr. Moore's paper presents such excellent geological data which must have been obtained only through physical hardship in this most difficult region that I do not presume to discuss it in detail. However, as he has not especially discusseed petroleum possibilities a brief memorandum on that subject may be added. Several years ago a

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[45]Gilbert, G. K., loc. cit., p. 4.
[46]See W. T. Lee, loc. cit. p. 48.

number of wells were drilled near Goodridge, at one time a post-office, on San Juan River, Utah. These wells were small, the best one yielding not over 50 barrels initial production. Also they were shallow, being less than 300 feet deep. Structurally these wells are in a syncline This structure is small but very well defined. It seems probable that the unusual position of the oil in the structure is explained by the aridity of the climate and by the deep trenching of the strata by the canyon of the San Juan River. The rainfall is meager and of the torrential type when it does come, so that the percent of run-off is great and the proportion of water that goes into the ground small. Also the deep canyons offer opportunity for any water above the level of the canyon floors to escape. Therefore the strata are dry. There is no water to lift the oil into the anticlines and it rests in the synclines. It simply obeys the laws on which the anticlinal theory is based.

JOHN L. RICH: About two years ago it was my privilege to trace certain of the formations described by Doctor Moore across New Mexico. Mr. Hager says he has traced the Coconino sandstone from the Grand Canyon across Arizona to the Fort Defiance uplift. Farther east, at the east end of the Zuni Mountains, is a series of red shales and sandstones resembling the Supai formation, overlain by typical Coconino sandstone, and that in turn by a limestone, evidently the Kaibab. Farther east in the Socorro district, is the same series of rocks, having the same general characteristics of sequence, color and composition, but there called the Manzano group with the Abo-Yeso red beds at the base, correlating with the Supai formation, a massive unnamed sandstone above, the equivalent of the Coconino, and the San Andreas limestone at the top, corresponding with the Kaibab. Farther east the same formations may be traced into Guadalupe County and the massive sandstone beneath the San Andreas is found to be the same as the Glorieta sandstone, which caps Glorieta Mesa. Thus the Supai, Coconino and Kaibab formations of the Grand Canyon may be traced eastward to east central New Mexico where they correspond to the Abo-Yeso, Glorieta and San Andreas formations of the Manzano group.

MAX W. BALL: I have been asked by some of my neighbors in which of the formations so clearly described by Dr. Moore oil is found. Production in Utah, although in small quantity, has be found at two horizons, the Goodridge and the Moenkopi. In the San Juan field of southern Utah, between 30 and 50 miles west of the town of Bluff, a number of wells have produced oil from sands in the Goodridge formation of the Pennsylvanian. These wells have never been profitable, but they have produced oil in quantities that would have been commercial if the wells had been more favorably located with respect to transportation and market.

In a small area on the Rio Virgin in the extreme southwestern part of

Utah, a few wells have been drilled into the Moenkopi and have produced small quantities of oil. Production is said to have reached 10 barrels per day, and these small quantities have been sufficient to warrant production for a small local market.

In my opinion, and in that of a number of other geologists who have studied Utah carefully, the Moenkopi is the most promising of the pre-Tertiary horizons. Although this formation contains comparatively little organic shale or bituminous lmestone, the out-crops are oil saturated with a persistency that is astonshing. Along the Orange Cliffs on the west side of the Green River, and "Under the Ledge" along the Dirty Devil River, there are numerous oil seeps; some of which drip oil sufficient to fill a tin cup in a comparatively short time. Around the great uplifts of the San Rafael Swell and the Waterpocket flexure the Moenkopi shows evidences of oil in perhaps three out of every four canyons. In some of the exposures which do not appear to contain oil chloroform tests show the presence of oil in considerable amounts. I have been told that similar evidences of oil are present around the Circle Cliffs uplift.

Farther to the south, between the Colorado River and the Rio Virgin, the Moenkopi is very thin and gives practically no evidence of oil, and on the east side of the Green River, near Moab, the Moenkopi is for the most part unpromising. I am told that farther east oil is found at places on the east side of the LaSal Mountains in western Colorado.

The oil possibilities of the Moenkopi have not been tested by drilling through the formation on a favorable structure. The wells on the Rio Virgin are on anticlinal noses; the wells that have attracted much recent attention to Utah, those on Circle Cliff and San Rafael Swell, were started below the Monkopi: that at Huntington was started too high in the Cretaceous to reach the Moenkopi; the tests at Duchesne and Hill Creek start in the Tertiary. A well is now being drilled by the Ohio Oil Company on the Cainville structure, a rather favorable dome which will test the Moenkopi at from 3,000 to 3,700 feet, and a well is now being drilled by the Utah Oil and Refining Company on the Farnham anticline, a closed stucture, which should penetrate the Moenkopi at approximately the same depth.

A number of other more or less favorable structures are known under which the Moenkopi is within drilling depth. Among these may be mentioned the Woodside structure, a fairly large and well closed anticline, probably the most promising Moenkopi structure in Utah, lying off the northeast end of the San Rafael Swell; the Last Chance structure, lying southwest of the San Rafael Swell and northwest of the Waterpocket flexure, a gradual but definitely closed anticline cut by a small basalt dike; and the Desolation structure, a well defined and well closed dome, cut by numerous basalt dikes. The Leonard Petroleum Company is drilling a well on the Salt Wash structure, a relatively small and none too clearly closed structure underlain by the Moenkopi.

Thus the Meonkopi lies within drilling depth on at least five favorable structures, of which two are being tested. The Goodridge sand, judging from observations in the Colorado River canyon and elsewhere, is probably of importance in only a small part of southeastern Utah, although it and related sands may be of importance in parts of southwestern Colorado.

C. W. TOMLINSON: The section exposed on the San Rafael Swell, about 100 miles north of the Circle Cliffs area, is very similar to that shown by Doctor Moore in the Circle Cliffs. Further, the strata here correlated with the Kaibab show striking similarities to part of the Park City formation of northern Utah, which in turn is correlated with the Embar of Wyoming. Also the Coconino or Aubrey sandstone of the San Rafael Swell can be correlated with much confidence with the Weber quartzite of northern Utah, and thence with the Tensleep of Wyoming. The Morgan red beds of northern Utah then match with the Amsden of Wyoming and part at least with the Supai of southern Utah and Arizona. The Redwall surely includes a representative of some of the Carboniferous limestones of northern Utah and Wyoming. Thus the major stratigraphic units of the Carboniferous occur in constant sequence from southern Montana through Wyoming and Utah into Arizona and New Mexico.

CHARLES SCHUCHERT: I had not intended to say anything about Professor Moore's correlation, but after two speakers have endorsed "long-range correlations on the basis of similar rock characters" I think it advisable to ask the workers for more fossil evidence. Long-range correlations on the basis of lithology will not do.

The stratigraphic sequence of the Colorado Plateau has been hurriedly worked over by many geologists during the past sixty years, and an analysis of their correlations shows that while each and every worker has added more or less to the sum of our knowledge, yet there is even today no complete agreement. The region is a most difficult one in which to make out the sequence, because of the several unfossiliferous sandstones and the rapid transition of the limestones into shales and sandstones. Finally, the source of the sandstones and shales was varied, for high lands existed not only to the north and in eastern New Mexico, but even more so in northwestern Mexico.

Not only should these things make for caution, but the further fact that the fossils do not always tell the correct geologic age, since some "Permian" fossils (those of the Kanab) are now known to be of early Triassic age.

A few years ago the speaker visited the Grand Canyon at Bright Angel, and found the Coconino sandstone, of Permian age, resting disconformably upon the Upper Supai red beds (290 feet thick), also of Permian age according to the plant evidence collected by him and identified by David White. Below the occurrence of these plants there is a

marked erosinal unconformity, followed by the Lower Supai (900 feet thick) of similar red beds, all of which appear to be representative of but a small part of Pennsylvanian time. Some of the uppermost Redwall limestones in the region of Bright Angel may be Pennsylvanian in age, but the greater part are clearly of Lower Mississippian (Madison) time. This stratigraphy has been described in the American Journal of Science for May 1918, pp. 347-361.

RAYMOND C. MOORE: With Professor Schuchert's remarks concerning the difficulty of precise and definite correlation of an unfossiliferous rock series which exhibit somewhat varying lithologic characters in different regions I am entirely in accord. However, such remarks can hardly apply to more than a portion of the stratigraphic section of the plateau province, for one of the most striking of all the remarkable features in the geology of this region is the surprising uniformity in lithologic character of some of the stratigraphic formations, permitting confident recognition over thousands of square miles of various key horizons which are at least homotaxially equivalent. It enables five Survey geologists working independently in different parts of the plateau country in southern Utah and northern Arizona during the last field season to compare in detail the stratigraphic observations made, to identify corresponding units throughout the region, and to recognize equivalent units described by other workers. Field work has traced some of the formations continuously for hundreds of miles and I believe there can be no reasonable question concerning the equivalences of the majority of the Circle Cliffs formations and those of exposures even at long distances in certain directions.

Concerning the Coconino-Supai portion of the section, to which Professor Schuchert particularly refers, and, it might be added, concerning a number of features in the Moenkopi, there are questions which can be settled, if at all, only after detailed field work in which the formations are followed practically without break throughout the region. For example, while identical stratigraphic position, relation to adjoining formations, lithologic character and numerous fossils allows no uncertainty as to the equivalence of the limestone identified as Kaibab in eastern Garfield County Utah, with some part at least of the Kaibab limestone of the Grand Canyon country, the relations of the sedimentary rocks beneath the Kaibab in these two regions are quite uncertain.

ROCK DISTORTION ON LOCAL STRUCTURES IN THE OIL FIELDS OF OKLAHOMA

JAMES H. GARDNER

By distortion is meant the state, condition or effect of being malformed or twisted out of shape. In this case, distortion refers to sedimentary strata associated with local small sharp folds at rather remote distances from areas of major deformation. Is it not remarkable that the local bending of the earth's stratified rocks has progressed with such great regularity that the individual layers of rock are, as a rule, so little distorted or changed from their original state? Tremendous forces have been necessary to lift and fold so great a thickness of sedimentary rocks as the whole of the Paleozoic system; yet, there is abundant evidence that in the oil fields of Oklahoma all of the series which are here represented in this great system are folded on each individual structure all the way from the surface down to the pre-Cambrian complex, which in all probability is itself correspondingly folded. At the time of deformation several thousand feet of sandstone, limestone and shale strata were involved. From the original deposition of stratum on stratum which was laid down for the most part in fairly uniform continuity and regularity of bedding, we now find monocline, terrace, syncline, dome and their various modifications all reasonably near to some area where geodynamic forces have culminated in an area of diastrophic movement.

All of these structures, including the range of crystalline mountains, the geanticline or "uplift" and the local folds of the oil fields, are areas of rock failure or incompetency; using in this sense, the terms of Leith, Chamberlin and Willis. The combined strength of the strata has been overcome in each area of folding, both regional and local. Whether the forces were applied laterally or in a large measure vertically, is a matter which will be discussed and on which the matter of epiclinal distortion has a bearing, and on which we are gaining new light. All are agreed that the strata have been deformed

at considerable periods of time after their deposition and at great depths below the surface where the load of overlying beds was very great. Formations which now lie at the surface, were deeply buried at the time of folding. A long period of subsequent erosion and removal of sediment has taken place since the period of deformation, so that we are now enabled to see along the outcrop stratified rocks which carried a great load and on which there was exerted a tremendous pressure when they were folding.

Notwithstanding all this, the strata have been lifted and flexed with an impressive regularity. Parallel beds of rock of nearly uniform thickness have been bent and arched in many cases without notable disturbance of their primary form. Each bed has preserved rather uniform thickness without undergoing disruption of its individual rock structure. However, it is just the exceptions to this rule to which the writer is here calling attention. It is his observation that in many cases strata lying now at the surface on local folds, particularly on the axes or flanks of domes, anticlines and synclines show plainly that they have not preserved their original form; that their strength has failed against the forces of folding and that as a result they are distorted.

The matter of local distortion on folds has a commercial or economic application, in that it is one of the distinguishing features of flexure and may lead to the discovery of a good structure or to further evidence of folding in areas where exposures are meager. Taken in consideration with other corroborative evidence, it has a scientific application with reference to the nature and origin of the forces that caused the deformation. The writer is not aware that this feature of structural geology in the oil fields has been previously discussed in public, except in his recent oral reference to the same before a meeting of the Tulsa Section of the American Institute of Mining and Metallurgical Engineers.

Geologists generally have not observed closely the evidences of distortion, but have been inclined to believe that all irregularities in an individual rock stratum are only cross-bedding or were caused by other factors connected with original deposition. However, the responses from a number of geologists

Fig. 1. Distorted sandstone (Pennsylvanian) on east flank of structural dome Sec. 26, T. 23 N, R. 7 E. Osage County, Oklahoma. Note that bedding plane C-D shows an offset at point E where it is intersected by distortion plane A-B; the latter ends at point E and is clearly of later origin than time of deposition. To the left bedding plane C-D is cut off by distortion plane J-K.

Fig. 2. A further example of distorted sandstone (Pennsylvanian) in a detached fragment showing parallel bedding planes squeezed out of original form. Sec. 26, T. 23 N. R. 7 E. Osage County, Oklahoma.

have been favorable in substantiating the fact that local distortion does exist, even in connection with local folding of the low degree of intensity and comparative mildness that characterizes the oil fields of the Mid-Continent region.

Let us diverge from the petroleum industry for a moment and recall some of the structural features of the sedimentary rocks as shown in the coal fields. Coal mining permits underground observation of the effect of structural movement on stratified rock. Coal is mined in rocks which have undergone various degrees of movement, from the normal, nearly level bituminous beds of the interior basins to the closely crumpled and faulted strata of the anthracite fields. In coal-mining, we meet with the terms "mashing" and "squeezing" in connection with areas of local and comparatively mild disturbance. Frequently a coal bed squeezes out at a particular point, and an abnormal thickness of coal lies adjacent to the "squeeze-out," showing a mashing, crawling or deformation of the bed from its original natural thickness. This necessarily results in a change in the structural composition of the coal. So it is in the oil fields. Beds of shale frequently "mash" or "squeeze" to abnormal thickness or thinness on the local structures. Two columnar logs of nearby wells may correlate at the top of the logs and also at the bottom of the logs, whereas one of the logs will show a greater thickness of material in the central portion than the other, so that one log must be crumpled or shortened in comparison with the other in order to adjoin consistently the tops and bottoms of the two adjacent logs. This condition can readily be explained by the theory of "squeezing" or "mashing" of the clay-shale beds involved in the section. The sudden inconsistent deepening of an oil sand, or rise of an oil sand, as compared with closely adjoining logs, where not indicated in the shallower beds, generally can be explained satisfactorily only on the theory of a "squeeze" or distortion of the overlying beds of shale. Furthermore, it is possible that an oil sand itself, in some instances, has been "squeezed" out, or suddenly "thickens" or "thins," from adjustment to the forces that produced the local folds.

What would be the effect of rather pronounced local fold-

ing on a very soft, unconsolidated sandstone deeply buried and consequently carrying a heavy load? This query refers to a loose incoherent sand that would permit of the creeping or crawling of the sand grains to spots of least resistance. Does the theory of distortion or adjustment to the forces of folding in such a case seem unreasonable? The sudden thickening or thinning of oil sands on structure may not always be due entirely to the factors of deposition. Some of their inconsistency in thickness and porosity may be due to their having been subjected to strong dynamic forces.

The writer has observed distortion in beds of sandstone, shale and limestone, as illustrated in part by the accompanying photographs. In the case of shale, distortion is usually in the form of local "squeezing" or sudden changes of thickness accompanied by an irregularity of the bedding planes. In this connection, however, the observer should be careful and not confuse distortion with exfoliation due to weathering or to concretionary growths in the shale mass, if he is basing his observations on surface exposures. In the case of limestone, distortion is least observable,—due, perhaps to the competency or resisting ability of such rock,—but in the case of sandstone, it commonly is evident. In most instances it shows plainest in the massive, softer beds of sandstone which were least able to resist the forces placed upon the whole stratigraphic section in which they occur.

The fact that the clastic sediments are in some cases irregularly deposited, showing wave-action or current-action, in the form of cross-bedding or false-bedding, coupled with the various irregularities due to weathering, leaves ample room for overlooking the evidences and importance of structural distortion. A close observation of the exact nature of the rock structure will reveal that cross-bedding or false-bedding, concretionary segregation of mineral matter, spheroidal weathering, and small rock-folds due to weathering, such as descried previously by Campbell,[1] can readily be recognized as such. Distortion due to deep-seated folding under a heavy load likewise can be recognized and is of definitely

[1]Campbell, Marius R., Rock Folds Due to Weathering, Jour. Geol. Vol. XIV, Nov.-Dec., 1906.

Fig. 1. Distorted sandstone (Pennsylvanian) on south flank of dome in south portion T. 21 N. R. 10 E. Osage County, Oklahoma. Bedding planes A-B and C-D are severely distorted in parallel fashion. Distortion plane G crosses the upper bedding plane and ends by a curve in the central stratum.

Fig. 2. Distorted sandstone (Pennsylvanian) near the top of the Cushing anticline on Jackson Barnett lease N. ½ S. E. Sec. 5 T. 17 N. R. 7 E. Creek County, Oklahoma. Note that bed A-B is thinned down at point C and that bed E-F is correspondingly mashed at point G.

different character. In the case of distortion, the massive layers frequently show "distortion planes" and in other instances the bedding planes are bent and warped, showing a similar condition, on a lesser scale, that is so evident in a polished slab of marble which was at one time stratified limestone. There can be no question about the distortion of rock structure in so intense a metamorphic action as one which produced marble from limestone. In the case of localized minor distortion on the gently folded rocks of the oil fields, however, only the initial stages of this change is evident, and then only as an exception to the rule. It is observable under special conditions with respect to the nature of the fold and to the failure of certain individual strata to resist compression uniformly. In making observations for distortion on these milder types of folds, the observer should search especially for certain layers of rocks, particularly the softer beds of sandstone, which, due to their inability to preserve their original forms, have held a permanent record of the forces of compression to which they have been subjected. It is not every structure that will have such beds exposed on the surface. They are more apt to be found in areas where massive sandstones of varying degrees of resistance now lie at the surface. For the purpose of identifying distortion as contrasted to false bedding, the reader should carefully note the accompanying photograph which shows a distortion plane cutting across a bedding plane producing a slight off-set. This proves the distortion plane a structural feature and of a later date than the deposition.

This brings us to the question of whether or not, when distortion is definitely recognized, it is due to compression caused by the weight of overlying sediments. In other words, is it an expression of consolidation and settling following deposition? In reply the writer wishes to state that he has given considerable time and observation to the question of whether distortion of the degree here described is confined to the areas of local folding or is generally present in the strata throughout the oil country. He has concluded that it is characteristic of the areas of local folding; that it occurs on the axes and on the flanks of local folds of various

PLATE III.

Fig. 1. Limestone beds (Pennsylvanian) south side west end of structure in Burbank Field. Sec. 6 T. 26 N. R. 6 E, Osage County, Okla. Bed A-B is thinner at points C and D of the lower stratum. Note thicker portion between points A and B compensated by thinner portion between C and D showing adjustment later than time of deposition.

Fig. 2. Detached piece of sandstone (Pennsylvanian) from distorted bed showing typical curved or cup-shaped outline. Sec. 26 T. 23 N. R. 7 E. Osage County, Oklahoma. Distorted sandstone in place at top of hill.

types. It is frequently, and perhaps most often observable fairly well down the flanks of anticlines. A sandstone that shows distortion on a local fold, tends to lose its characteristic warped or mashed structure whent its outcrop passes beyond the area of deformation. In areas remotely removed from local folding where the rate of dip clearly is uniform and constant, the writer's experience indicates that the different strata are undisturbed from their original form of deposition except as altered by settling, weathering and erosion. In other words, distortion of the nature to which the writer refers is, in such areas, conspicuous by its absence.

For some years the search for new oil pools in the Mid-Continent field has been confined largely to the areas where the outcropping of strata were sufficiently complete to define the nature of the folding. In such areas, differences of opinion on the nature of the structure have been chiefly a matter of the degree of accuracy in mapping. But in the future, drilling will be done in districts where the rocks are largely concealed and where the evidence of structure is incomplete. In such cases, observation of distortion is applicable even though it merely be the evidence on which core-drilling is done to define definitely the true structural conditions. Distortion of a stratum in any particular district is a raised finger of warning signifying that in this vicinity the strata have yielded to forces which have given them an upward lift of more or less importance.

In Volume I, of the Bulletin of the Southwestern Association of Petroleum Geologists, the writer delivered a paper entitled "The Vertical Component in Local Folding." He still maintains, and has been supported in his opinion, that the theory set forth on that occasion is substantially correct: that in the zone of observation the main application of the forces of local folding have been vertical rather than lateral. It is believed that the local folds of the Mid-Continent oil fields are not the result of tangential pressure moving outward from an area of maximum lift, such as the Ozark and Arbuckle areas, but that these smaller folds are the result of the same pressure that produced the larger lift; that they are smaller expressions of the same thing and not secondary

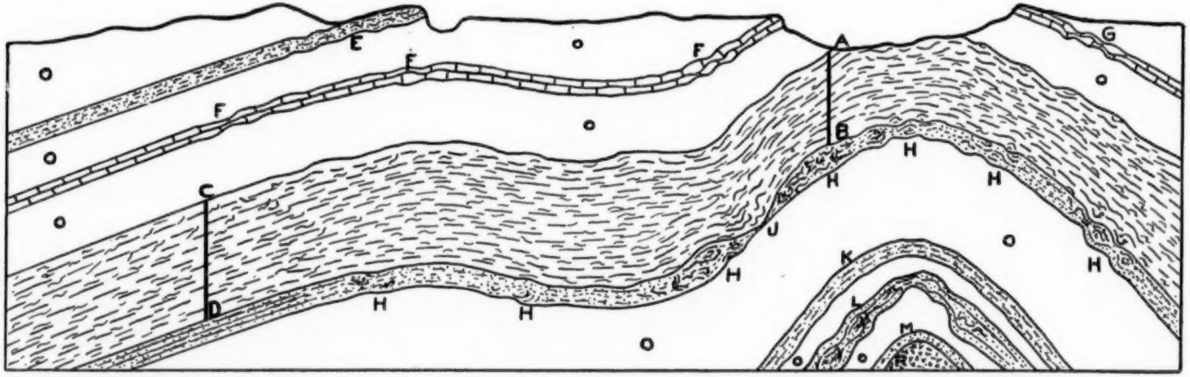


Plate IV. Cross-section illustrating deformation and distortion in Mid-Continent Fields. Note slight distortion of limestone at points F and G and sandstone at points A-B is thinned down below normal thickness shown at C-D. Sand at point J is mashed out and thickened in adjacent portion. Sandstones M and K are resistent beds not distorted. The granite core at point R is folded in conformity with the clastic rocks above.

results; that they were probably coincident and represent areas of failure to withstand deforming forces, the components of which were essentially vertical.

In the case, for instance, of the local structures of Kansas and Oklahoma, the writer believes that each of the domes, anticlines, terraces, noses, etc. that stand separate and distinct from all others, is an expression of the initial stage of folding due to an uplifting force which culminated or reached its maximum orogenic development in the central Ozark, Arbuckle and Ouachita regions. The deep seated flow of rocks toward that area of least resistence relieved the pressure from the adjacent smaller folds and thus, instead of the central area being the cause of their development, it really stopped the folding in the smaller areas. The local folds were relieved and arrested when the pressure was released to the larger area of structural failure. The nature of the folding is consistent with this idea and here the localized distortion on the flanks of anticlines has a scientific bearing that points to the same conclusion.

There is considerable evidence that compression incident to folding has reduced the normal thickness of the stratified section in the areas of local deformation. Well logs on the structures show a shortened or abnormal interval from the surface down to the oil sands. Well logs off the structure in normal areas, show a greater thickness for the same sediments. Recently in discussing deformation or distortion with the geological department of the Marland companies, the writer learned that in the Ponca City region, the sedimentary section is shorter on the folds than in the normal undisturbed areas of the same region. This condition was indicated also by Conkling[2] in his study of the Cushing structure and by Edwards[3] in his cross-sections of the Burbank field. It seems to hold generally throughout Oklahoma. Thus, it is possible that the forces which caused the deformation acted upward from a deep-seated source and in doing so, the softer beds were

[2]Conkling, Richard A., The Influence of the Movement in Shales on the Area of Oil Production, Am. Inst. Min. Engi., Vol. 56, pp. 876-879, 1917.

[3]Edwards, O. M., The Burbank Oil Field, Am. Assn. Pet. Geol., Meeting March, 1922.

compressed into a lessened thickness and the incompetent strata preserve this record in the form of distortion.

A further suggestion is warranted that since a slight alteration of shale by compression may be indicated by chemical analyses showing the loss of combined water, then a close chemical study of the rocks on the local folds may prove the presence of slight localized metamorphism. In this connection there is a bearing on the theory of the genesis of petroleum and natural gas in connection with local deformation, as some authors have recently advocated. Moreover if it should be established that a greater degree of metamorphism exists on the local structures than in the territory immediately surrounding them, then such metamorphic action may have been more intense along the axes of anticlines and domes than elsewhere. This fact if demonstrated would account for the hardening of the oil and gas sands at the tops of structures as in many instances appears to be the case.

In the case of lifting a segment or detached load in the absence of friction or flexure, the law that "action is equal to reaction" applies and no extra pressure to speak of is necessary to raise such a load of overlying rocks. But in the case of lifting and folding from a given focus of pressure a condition exists similar to raising a tent from a central mastpole; an extra pressure is necessary at the point of application due to the weight of the material on the flanks and to the resistance against folding. There is a tendency to break through at the point of pressure as is true in the case of an intrusive volcanic plug; thus the strata above the point of lift must transmit the pressure to higher strata and are consequently subjected to greatly increased compression, resulting in distortion and lessening of the thickness of the compressible beds above the area where the pressure is applied.

DISCUSSION

W. E. Wrather: Mr. Gardner attributes the local thickening of strata of limestone shown in the photographs to compression. If this is true, the compression must have taken place before consolidation; or if it took place after consolidation, some evidence should be present in the form of fracturing, or of a crystalline character of the limestone due to metamorphism. Were such results noted?

J. H. GARDNER: The matter of metamorphism in connection with localized distortion is a subject the writer is greatly interested in and hopes to consider at our next annual meeting. At the present time, he is lacking in both thin sections and analyses which might throw light on the question that Mr. Wrather brings up with respect to a change in the crystalline character of the limestone beds on local structures. He is pleased to have this suggested field of research in connection with a study of the shales as referred to in the paper. The distortion is, however, of rather low degree at most, and the petrographic and chemical evidences may prove to be correspondingly slight and not easily demonstrated.

C. T. KIRK: The observations of Gardner in flat-lying strata might be repeated upon the many and intensified instances found about Lake Superior and in the Appalachian Mountain region. They have been analyzed more or less carefully by Leith in Bulletin 239, U. S. Gological Survey, and earlier in more or less experimental fashion by Willis, Annual Report XIII, Part 2, U. S. Geological Survey.

The epiclinal features are generally the result of the splitting or spalling of a rigid or competent bed confined between more yielding formations, and appears analogous to Leith's fracture folding phenomena.

J. H. GARDNER. Mr. Kirk's remarks with respect to the fracturing of the rigid beds between the yielding strata brings out an interesting angle of the question which appears very consistent with the observations here set forth and should receive further study.

F. G. CLAPP: Many evidences exist throughout the world, not always associated with local folding, of distortion produced by what might be termed isostasy on a small scale. Examples of such distortion may be interesting.

Many years ago W. H. Niles described in print some disastrous sudden expansions of rock that had taken place in, I think, Triassic sandstone quarries of the Connecticut valley of central Massachusetts. Great slabs of stone broke out without warning and with great force from the flat-lying beds in the bottom of the quarries, killing one or more men, if I recall correctly. The cause of the accident was supposed by Professor Niles to be due to the weight of the rock in the sides of the deep quarries transmitted through the rocks to the quarry floor, which yielded in consequence at the points of least resistance.

In Dickson County, Tennessee, farmers tell of several what they call "gas blowouts" which have occurred in recent years. The formation of the surface of the region is Mississippian limestone, dipping only slightly and comparatively thinly bedded. The valleys are several hundred feet deep and are V-shaped, only a few rods wide at the bottom. The "blowouts" consisted of sudden expansion of the limestone with considerable noise over a few square yards at certain spots in the bottom of the deep-

est valleys, and the probable veracity of the reports is attested by the appearance of small holes, several feet across and a few inches deep in the limestone valley floor. Only slight gas pressure exists in any of the test wells put down in that part of Tennessee, and the wells are not deep enough to have high rock pressures. My view, on examining the spots, was that the "blowouts" were caused by the weight of the rock on the sides of the deep valleys, transmitted through the hills to the valley floors.

A third illustration was seen on my trips to central China, in northern Shensi Province, where narrow V-shaped valleys are numerous. The formation is Carboniferous sandstone and shale, exposed only in the lower parts of the deepest valleys, but where the solid rocks are overlaid by hundreds of feet of Recent loess, sometimes separated from the Carboniferous by a few feet of Pleistocene sandstone or gravel. A number of minute anticlines were seen by my associates and myself, the size being 5 to 15 feet in height and of about the same width. They generally extended transversely to the walls of deep side valleys, not far from where these valleys join the main valleys. Whether or not any of the distortions are parallel to the sides of the valleys is not certain. Some of the distortions extend from the Carboniferous rocks upward through the overlying Pleistocene deposits into the base of the loess. Mr. Fuller, who also examined the features, believed them to be due to the weight of the surrounding hills transmitted through the valley walls to their floors at the points of least resistance, where the distortion took place, and I am inclined to agree with him.

Summarizing, we have three regions (widely separated) from which distortionary features are here described, all of which would appear to be due to the weight of overlying sediments.

C. E. Decker: A number of small sharp folds have been reported in northern Oklahoma associated with faults, some of which are said to be thrust faults. These folds and thrust faults seem to indicate a more marked lateral than vertical component in the stresses which deformed the rocks. I should like to ask Mr. Gardner if he found any marks on the surface of the limestones to indicate that they were deformed before the surfaces became hardened. It would seem to me that such thickening in heavy limestone beds could not take place unless the deformation took place before they hardened, particularly as they do not show close folding.

With reference to Mr. Clapp's statement, I should like to ask if he has attempted to calculate the amount of the stresses developed by the weight of valley walls, the pressure of which has been given as a cause for folds in the bottoms of many valleys. When the weight of the rocks in these walls is figured, it is so small that it is probably not strong enough to overcome the strength of the weaker shales and much less so the sandstone beds which are included in many of these folds.

FREDERICK H. LAHEE: There is one phase of this discussion which, I think, has been touched upon only by Dr. Decker. He stated the possibility that pronounced thinning and thickening of the limestone shown in one of Mr. Gardner's photographs may be the result of squeezing of the limy materials before these were consolidated. To my mind this is an important point which deserves serious consideration.

There are innumerable evidences of deformation, not only of limestone, but also of sandstone, shale, and other sedimentary rocks, before these rocks were consolidated. There is also an abundant literature on this subject. This kind of structure I have previously referred to as "contemporaneous deformation."* It may be due partly to the slipping and settling of some beds on others, a phenomenon which has been proved to occur in clayey materials on slopes of exceedingly low inclination; and it may be due partly to irregular compression of the sediments. However, in both cases it *precedes* consolidation and probably, also, in most cases it precedes the accumulation of any great overburden.

In the northern states there are many cases where the aqueoglacial sands exhibit small faults not continuous through the sand body. This sand is now quite unconsolidated, yet the faults are clear-cut and sharp. Two or three miles east of Donie, in Freestone County, Texas, are unmistakable evidences of crumpling, sliding, and fracturing of Tertiary clayey and sandy materials previous to their consolidation.

In looking at Mr. Gardner's illustrations, it seemed to me that at least 75 per cent of the structures shown were typical of contemporaneous deformation, that is, of local folding and faulting prior to and unrelated to diastrophic deformation. The picture showing a small fault in sandstone, sharply terminated upwards against more of the same sandstone, seemed to me adequate evidence that the displacement occurred during the deposition of this stratum.

Now, there is another point suggested by Mr. Gardner's interesting paper. We have recently had the experience of drilling high on a good anticlinal structure and finding that the sand, which is well represented on the flanks of the fold, is entirely absent on the crest. I am informed that this has been the experience of others in parts of Oklahoma and Kansas. I cannot explain the feature except as a consequence of folding during sedimentation. It would seem that the fold must have existed then as a low swell from which the currents carried the drifting sand and round the flanks of which this sand accumulated.

If we may explain the *absence* of a sand bed on top of an anticline and its presence on the flanks of the fold as the result of gradual arching during sedimentation, may it not be possible that the *thinning* of a sand or of a series of beds over an anticline may be similarly explained? I can

*Lahee, F. H., Field Geology, 1st ed., p. 75.

hardly believe that the slight bending which has produced the weak folds of the Mid-Continent field—folds in which we are accustomed to designate dips as so many feet per mile—has been mechanically sufficient noticeably to modify the thickness of single strata, or groups of strata, so folded. I believe that these marked variations in thickness of beds, as now measured, are due principally to conditions of deposition and differential settling.

MAX W. BALL: In the Duchesne region in the Uinta Basin, Utah, there are some extreme illustrations of what Mr. Gardner has called epiclinal movements. There are in the region considerable quantities of hydrocarbon known as ouijaite. This is a breccia consisting of angular fragments of limestone or limy shale in a cement of hydrocarbon of the gilsonite-elaterite series. In some places at least, the bed of limestone or limy shale has apparently been brecciated of the differential movements overlying and underlying beds. These beds, having been stronger or less brittle than the intervening bed, have moved without breaking, while the interlying bed has been broken into fragments, and the interstices filled by the hydrocarbons which are so abundant in the formation. At Duchesne, also, is a suggestion of the correctness of Mr. Knappen's statement that folding and faulting may have been rather generally caused by different horizontal movement. The numerous faults along the Clive anticline have much greater horizontal than vertical throw. There are strike faults along and parallel to the axis of the anticline. The vertical components are from 5 to 200 feet, the horizontal movement parallel to the trace of the fault plane is in some instances as great as a mile.

WALLACE E. PRATT: I desire to learn a little more about Mr. Gardner's Greek word "epiclinal." "Epi", I have thought, means "on," "clinal" means "inclined, tilted or leaning." It does not mean folded. Yet clearly Mr. Gardner uses epiclinal to indicate "on the fold." Would not "epi-anticlinal," under the conditions stated, be a more exact term?

C. K. LEITH: (In letter to Mr. Gardner).

Your paper seems to be very interesting and suggestive, but I do not feel that I have enough special knowledge of the territory you have in mind to make any definite constructive suggestions. There is no doubt that minor structures are often very useful as a key to the major structure, but it is also true that in some places there are local disturbances due to original sedimentation, consolidation, or secondary deformation, which are apparently unrelated to the major structures or may exist in otherwise flat and undisturbed beds.

Your paper seems to be written mainly with the idea of calling attention to this field of investigation, but you do not go into specific inferences that might be drawn from the specific structures.

GEOLOGICAL NOTES

POSSIBLE OIL IN SOUTHERN UTAH

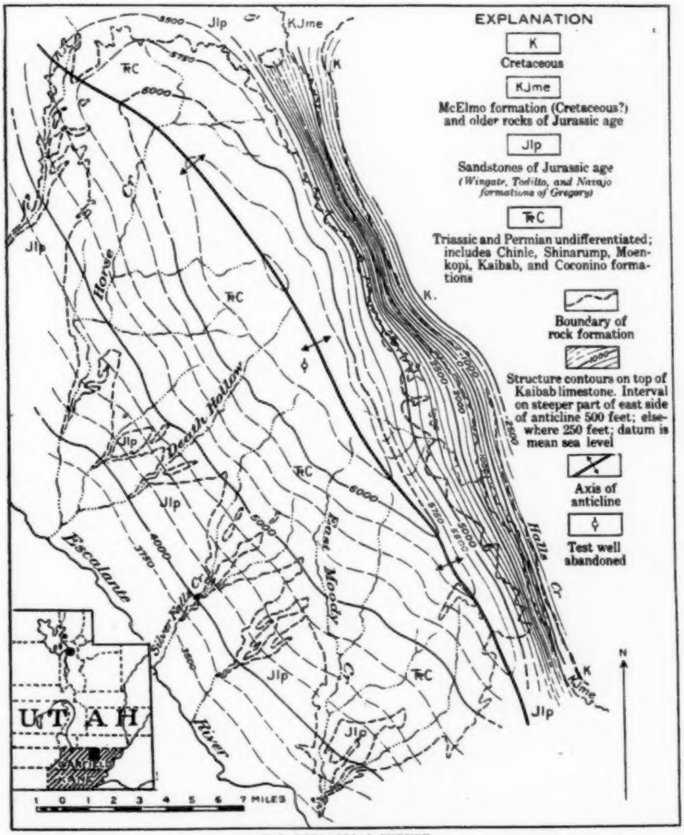
The discovery of light oil of good grade in southern Utah and the knowledge that there are some large anticlines in that region has attracted oil operators to that part of the State Oil has been obtained from wells in two districts in Utah, one on San Juan River, some miles west of the town of Bluff, in San Juan County, the other near Virgin City, in Washington County. Little oil has been produced commercially in either of these districts, however, partly because of the great difficulties of transportation but mainly because of rather unfavorable geologic conditions.

The possibility of obtaining oil in southern Utah in the region between and somewhat north of the two small oil fields just mentioned was investigated during the summer of 1921 by the United States Geological Survey, Department of the Interior. A party under the direction of R. C. Moore made a reconnaissance examination of much of Kane and Garfield counties and completed a detailed survey of the large structural dome in eastern Garfield County known as Circle Cliffs. The essential objects of the survey were to locate structural features that indicate favorable places for prospecting for oil, to trace accurately the geologic formations that are exposed in the region, to examine the rocks for indications of oil, and to make a special study of the structure of the Circle Cliffs.

The surface rocks in south-central and southeastern Utah consist chiefly of sandstone and shale that range in geologic age from Pennsylvanian to early Tertiary. As this region is almost a desert the rocks in it are exposed nearly everywhere, so that the surface geology and the structure may be determined readily. The chief geologic units are the brilliantly colored Tertiary formations that compose the highest plateaus and that may be seen in numerous exposures, as in the scenically famous Bryce Canyon, southeast of Panguitch; the Cretaceous beds, which form Kaiparowit Plateau and the prominent table-lands near the Henry Mountains; the remarkable thick, massive cross-bedded Jurassic sandstones that have been called by Gregory the Navajo and Wingate formations; the chocolate-colored and varicolored shales and sandstones of the Triassic and Permian; and the thick beds of Pennsylvanian limestone. The total thickness of the rocks exposed in this region is more than 13,000 feet. The younger rocks appear to lie mainly in the northwestern part of the region in the higher lands; the older rocks mainly in the southeastern part, in the canyons of Colorado and San Juan rivers and their tributaries.

Rocks saturated with oil or containing noticeable indications of it were found in parts of the Moenkopi formation (Triassic) in the Circle Cliffs, and showings and seepages of oil were found in the overlying Shinarump conglomerate, also Triassic, in the Circle Cliffs and along Colorado River

above the mouth of the Escalante. Oil-saturated Moenkopi beds have also been found in the San Rafael Swell. The oil-bearing formation of the San Juan field is older than any rocks that appear at the surface in



U. S. GEOLOGICAL SURVEY
STRUCTURE MAP OF THE CIRCLE CLIFFS, GARFIELD COUNTY, UTAH

Fig. 1.

Kane and Garfield counties and is therefore not exposed here, but it should lie within drilling depth beneath Circle Cliffs.

The Circle Cliffs form one of the largest and best defined anticlines in

southern Utah. The cliffs, which are composed of Jurassic sandstone (the Wingate formation of Gregory) form an almost impassable wall that surrounds a lower elliptical area about 10 or 12 miles wide and 30 miles long. The longer axis of this cliff-walled inclosure trends north-northwest. The rocks within the cliffs belong to the Triassic and Permian systems, and the lowest formations (Kaibab limestone and Coconino sandstone) are found in canyons in the central part of the area. The Circle Cliffs consist of an asymmetrical anticline, whose crest, except at its north end, marks the main divide between the streams that flow southwestward into Escalante River and those that flow eastward into Hall's Creek. The anticline is really an especially high part of the great Water Pocket fold, which can be traced from a point beyond Colorado River on the south to Thousand Lake mountain on the north, a distance of about 80 miles. The beds on the southwest side of the Circle Cliffs anticline have a rather uniform dip, which for many miles amounts to about 250 feet to the mile. In the Kaiparowits Plateau, 25 miles distant, the beds are still inclined to the southwest, and the Kaibab limestone is there probably not less than 5,500 feet lower than in the central part of the Circle Cliffs. The beds on the east side of the anticline have a very steep dip, which averages about 30° but which is in places as much as 60°. By this downwarp the Kaibab limestone, which has an elevation of 6,500 feet in the highest part of the fold, is carried to a depth of 2,000 feet below sea level in a distance of 5 miles. The dip of the beds along the axis to the northwest and southeast is only about 70 feet to the mile, being thus much more gentle than the dip on either of the flanks. The closure in this anticline is at least 1,000 feet. At its south end the crest of the fold is rather sharp and narrow, but toward the north it becomes broader and less sharply defined. The detailed survey shows no minor domes or large terraces on the flanks of the main dome.

Near the town of Escalante there is a much smaller anticline with a steeply dipping west limb and a gently dipping east limb. The sandstone that has been called the Navajo by Gregory is the surface formation over the central part of this anticline. There are also in the region other minor structural features that have not yet been examined in detail. A test well started by the Ohio Oil Co., near the crest of the Circle Cliffs anticline in January, 1921, reached a depth of 3,212 feet in November, 1921, when it was abandoned. The drill penetrated about 1,660 feet of Coconino and Supai strata (Permian and Pennsylvanian?) and in the lower part of the well encountered thick limestone and sandstone that are probably equivalent to the Goodridge formation (Pennsylvanian), which contains the oil in the San Juan oil field. The failure to discover commercial accumulations of oil in these beds in this large anticline was a severe disappointment. Other test wells in the Circle Cliffs, even if drilled deeper, would probably not show different results, but this well by no means condemns other anticlines in this region, such as the geologically similar San Rafael Swell, farther north. The record of the Circle

Cliffs well is of high geologic value as an aid to the study of the Carboniferous strata in other parts of the Southwest.

As the Circle Cliffs well was started at a horizon below the oil-bearing sands in the Moenkopi and Shinarump formations, the lower parts of which crop out at the surface in Circle Cliffs, wells drilled to test the possibility of obtaining oil in commercial quantity from these sands must be located on favorable anticlines where the Moenkopi and Shinarump formations are not exposed at the surface and are within practicable drilling depth. In the anticline just east of the town of Escalante these sands lie about 1,700 to 2,000 feet below the surface.

Oil-bearing rocks occur in southern Utah, and prospecting in areas where the structure is favorable will be continued.

RAYMOND C. MOORE.

THE BELLEVUE POOL, LOUISIANA

The Bellevue pool is the youngest and in some ways the most wonderful pool in the North Louisiana oil field. It is in T. 19 N., R. 11 W., Bossier Parish, 17 miles northeast of Shreveport and the same distance southwest of the Homer pool.

The pool receives its name from the small village of Bellevue, 2 miles to the northwest, which was once the political center of Bossier Parish. The parish seat is now at Benton, 12 miles west. Bellevue is 6 miles north of Princeton, a station on the Louisiana & Arkansas Railroad. The wagon roads are unimproved. The most convenient way of reaching the pool is by automobile from Shreveport over 9 miles of hard surfaced pike to Red Chute, 10 miles of dirt road to Bellevue, and 2 miles southeast to Brown's farm, and at last, a 1-mile walk through woods and swamp to the wells. This 23-mile trip can be made in two hours.

Although a few wildcat holes had been drilled in the general area of east-central Bossier Parish, the first well-planned deep prospecting began with the completion of the Standard Oil Company's Heilperin No. 1 as a failure at 3,046 feet. This was in the year 1918 on a location in sec. 32, T. 20 N., R. 11 W., near Bellevue which, according to surface indications, seemed to be rather favorable. At the same time, or somewhat later, Mr. R. O. Roy, an operator and producer of Shreveport, was planning to drill about 4 miles farther south.

In 1919 and 1920 Roy's first two attempts, namely, Pease No. 1 in sec. 26, T. 19 N., R. 12 W., and Wyche No. 1 in sec. 14, same township, were abandoned as failures at 2,474 feet and 2,645 feet respectively, although each had penetrated the Nacatoch, Blossom, and Woodbine sand horizons and had found good showings of gas and some oil in the Nacatoch about 800 and 900 feet deep. In November, 1920, Mr. Roy completed a 5 to 15 barrel high-gravity pumping well at a depth of 2,173 feet (Woodbine formation) in sec. 7, T. 19 N., R. 11 W. This well never became a commercial producer but it gave evidence of oil in commercial quantity on the Bellevue structure.

Subsequently, in 1921, six deep tests were drilled within a radius of 6 miles of this first producer. None of these was far enough east up the dome to get production in the Nacatoch and none got encouraging showings in the lower sands. Of these holes, the Transcontinental Oil Co., Bliss & Weatherbee No. 1, in sec. 3, T. 19 N., R. 11 W., went to 3,014 feet, the Gulf Refining Co., Lyles No. 1 in sec. 13, T. 20 N., R. 12 W., went to 2,985 feet, and the Texas Co., Scanland No. 1 in sec. 29, T. 19 N., R. 11 W., went to 4,052 feet.

Meanwhile, Mr. Roy, with the co-operation of Mr. J. Y. Snyder, geologist, was drilling more test wells, principally shallow holes, and was finding the "gas rock" (Nacatoch) higher and higher toward the east. After drilling 10 or 12 holes, ranging from 200 to 400 feet deep, Messrs. Roy and Snyder, got the discovery well in the Nacatoch formation, with an initial production estimated at 6,000 barrels from a depth of 397 feet, 10 inches. This was the Hard Times Oil Co., Railroad Lands No. 7 in sec. 15, T. 19 N., R. 11 W., completed in the Nacatoch formation, November 13, 1921, about one year after the Roy-Smith No. 1 discovery well in the Woodbine.

The north half of T. 19 N., R. 11 W. is the area in which practically all of the drilling has been done and where all of the production has been found. Mr. Roy was the largest holder of leases in the area and the Louisiana Oil Refining Corporation owned more than 2½ sections in fee. After the discovery in the shallow sand, The Standard Oil Co. of Louisiana bought several hundred acres of leases. Other companies who bought comparatively large acreage are the Texas, Humble, Sun, Transcontinental, Arkansas Natural Gas, and Gulf.

Since the discovery well came in, about 30 wells have been drilled in the area of sections 9, 10, 11, 14, 15, and 16 where shallow production is found. Three of these were failures in saltwater, on the edge of the producing center. The 27 wells located in a compact area 1¼ miles long and ¾ mile wide have produced 88,000 barrels of oil to April 1, 1922, covering the first three months of the life of the pool. Of this total, 57,000 barrels were pipe line runs and 31,000 barrels were in storage. On March 31, the following operators, named in order of producing importance, produced 1,580 barrels: Louisiana Oil Refining Corporation, R. L. Autrey, Standard Oil Co. of Louisiana, R. O. Roy, Chandler & Collins, Gulf Refining Co., and Humble Oil & Refining Co.

The oil contains about one per cent basic sediment and salt water, although in one edge well the salt water amounts to 80 per cent of the fluid. The estimates of initial production in the Bellevue pool have been too high in some cases because of the foamy condition of the gushers. One well made several million cubic feet of gas with the oil. A sample of the crude shows a gravity of 19.3 Baume and contains 2.5 per cent gasoline, gravity 63.6 Baume; 2.5 per cent naptha, gravity 54.2 Baume; 7.5 per cent kerosene, gravity 43.3 Baume; 12.5 per cent gas oil, gravity

33.5 Baume; 30.0 per cent spindle oil, gravity 27.2 Baume; 38.0 per cent lubricating oil, gravity 21.3 Baume; and 7.0 per cent loss and coke.

Topographically, the Bellevue area is a somewhat featureless plain, particularly over the shallow pool where the surface is about 215 feet above sea level. In wet weather a small meandering stream is inadequate for drainage, and the surface becomes a swamp. In one or two places, open "prairies" break the monotony of wooded areas. Farther away, more noticeably 3 to 5 miles north and west along Bodcau Lake and Bodcau Bayou, the surface is rolling and breaks off in the bayou bluffs which drop 50 feet or more. Bellevue would not be selected for an oil field because of its topography.

Nor would the shallow pool, as now developed, have been discovered by its surface geological features. The soil is gray sandy loam and clay, rather uniformly characteristic of nothing except Quaternary and Recent formations. Dips of beds exposed at the surface throw little if any light on the structure.

A more extensive examination, however, of the area surrounding the producing wells results in the discovery of pronounced stratigraphic features indicating distinctly favorable deformation. Township 19 North, Range 11 West, has long been mapped[1] as a Tertiary inlier surrounded by Quaternary. More than this, subsequent work by many geologists has established the generally accepted fact that the limestone concretions of the older Wilcox formation are surrounded by marine clays of the younger Lower Claiborne and also by probably still younger deposits of Upper Claiborne, all of which are completely encompassed by Quaternary and Recent formations. Although this stratigraphic sequence from an old center to a young periphery may not be traced out in every direction, the exposures of these formations are sufficiently numerous to indicate the nature of the general structure as that of a truncated dome. The proof of this structure is found in the logs of wells drilled in this part of Bossier Parish and the adjoining part of Webster Parish.

The top of the dome as mapped on the producing horizon of the Nacatoch formation drops almost 1,800 feet in 6½ miles toward the northeast, or from 60 feet below sea level in the northwest corner of sec. 14, T. 19 N., R. 11 W. to 1,845 below sea level in the southwest corner of sec. 16, T. 20 N., R. 10 W. This is a dip of 275 feet per mile or about 3°. Toward the southwest it dips about 750 in 9 miles, or 83 feet per mile, or a little more than ½ degree. The dome has at least 600 feet of closure. Toward the west, it grades off onto the general level of the Sabine Uplift and toward the northeast it plunges off the Uplift into a deep syncline southwest of the Homer pool. The Bellevue structure may be described as a dome on the east side of the Sabine Uplift. Nowhere in the North Louis-

[1]Veatch, A. C., Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas, U. S. G. S. Prof. Paper 46, Pl. III., 1906.

iana territory does the Nacatoch come so near the surface without outcropping. On the present producing top of the dome, the Nacatoch is 289 feet below the surface, 60 feet below sea level, and has a structural relief of 200 feet. It is 500 feet higher than the Caddo structure, 600 feet higher than the Homer dome, 1,600 feet higher than the Haynesville fold, and 1,900 feet higher than the El Dorado, Ark., terrace.

The vertical section on the top of the Bellevue dome as now known shows a water sand under 80 or 90 feet of surface sand and clay; then about 150 feet of shale, probably Arkadelphia clay, representing the top of the Cretaceous to a depth of 250; then 50 feet or more of hard limestone overlying 10 to 20 feet of oil sand. Production is sometimes found in the limestone "cap"; sometimes in the underlying sand. Initial production ranges from less than 100 to several thousand barrels.

On the side of the dome, deeper test holes, such as the Texas Co.'s Scanland No. 1 in sec. 29, T. 19 N., R. 11 W., 3½ miles from the top of the structure and 300 feet down the flank, find the top of the Nacatoch at a depth of 600 feet, the Blossom at 1,500 feet, the Woodbine at 2,100 feet, and probably Lower Cretaceous sands at 3,100 feet. All sands known to produce elsewhere in Louisiana fields are easily reached by the drill in the Bellevue pool.

Small portable rotary rigs are used. Eight inch casing is set below the shallow water sand near 100 feet and 6-inch is set in the "lime rock" above the pay sand near 300 feet. One 8-inch and one 6-inch pipe line owned by the Standard Oil Co. of Louisiana and the Louisiana Oil Refining Corporation have been laid to loading racks 4 miles south on the L. & A. railroad.

The gusher pool of heavy oil in the Nacatoch is considered only the beginning of production on this dome. The favorable structure, comparatively shallow depths to the three lower sands, and encouraging showings in the deep test, indicate a bright future for Bellevue.

Shreveport, La., April 12, 1922. J. P. D. HULL.

A number of wells on the Bellevue dome have held up in production remarkably well. National Oil Company's (R. J. Barry, Trustee) Elston No. 2, in sec. 10, T. 19 N., R. 11 W., which came in with 1,000 barrels initial production has produced almost 40,000 barrels during the first six weeks of its life. It flowed 600 barrels daily the first eight weeks, 100 barrels daily the next two weeks, and is now flowing 300 barrels a day. It contains no basic sediment and no salt-water.

Drilling was originally done with "baby" rotary rigs, but better results seem to be had with cable tools, particularly with Armstrong rig No. 25, using gasoline as fuel.

Four days are needed to drill 300 to 350 feet where the first gas show is found in a limestone "cap" and 6-inch casing is set and cemented. After 10 days shut down to allow cement to set, the plug is drilled and

hole deepened 2 feet, or more, to the oil sand. The cost of drilling is about twelve hundred dollars.

Shreveport, La., April 18, 1922. J. P. D. HULL.

WEBSTER PARISH GAS FIELDS, LOUISIANA

Within the last six months a gas field has been developed in Northern Webster Parish, Louisiana, that gives promise of being as large as the Bethany, Texas-Louisiana, field and half as large as the Monroe, Lousiana, field.

Drilling for oil in northern Webster Parish was commenced in January, 1919, by Mr. J. K. Wadley and associates, of Texarkana, Arkansas-Texas. Five holes were drilled by different operators in the area east of Cotton Valley with indifferent results as regards showings of oil and gas, before the discovery well blew in, making several million cubic feet of gas, several barrels of oil, and several thousand barrels of salt water. The well blew wild ten days, was then capped, but when reopened, had bridged over. It was abandoned because of the bad condition of the hole.

This well was drilled by the Louisiana Oil Refining Corporation and J. K. Wadley on the Gleason farm in sec. 13, T. 22 N., R. 10 W., 6 miles due east from Sarepta, a station on the Louisiana and Arkansas Railroad. The location was made in July, 1920, on the evidence of extended sub-surface work and of Tertiary and Quaternary dips on the surface. The first hole was junked at 1784 feet, but the second attempt blew in uncontrolled from the Blossom sand at a depth of 2793 feet, on February 4, 1921. It had to be killed and a second well, Gleason A-1, 100 yards away was completed at a depth of 2788 feet, in August, 1921. It met a worse fate, however, than No. 1, for it not only blew uncontrolled with the drill stem in the hole, but it formed a crater, caught fire, and from March 7 to April 7, 1922, was a boiling, burning lake of gas, oil, and salt water. On the latter date, coincident with the pumping of mud into the Gleason A-2 which had been drilled 100 feet away as a relief well and coincident with the blowing in of the Fullilove and Wadley, Martin No. 1 about a mile away, the crater subsided and the fire went out, although the escape of gas and fluid is still uncontrolled (April 15th.) None of the wells, therefore, at the discovery location is commercially productive. Gleason No. 1 was conservatively estimated as making 15 million cubic feet of gas, 50 barrels of oil, and 3,000 barrels of salt water. The oil had a gravity of 25 Baume and the water contained 7 per cent. sodium chloride.

The first well to be succesfully drilled without being ruined by salt water was the Sinclair Oil Company's Mayfield No. 1, in sec. 20, T. 23 N., R. 9 W. This well had an initial production, September 20th, 1921, estimated at 10 million cubic feet of gas and a rock pressure of 1030 pounds per square inch. Since that time, four other large gassers have been completed, namely: Portland Syndicate, Munn No. 1 in sec. 1, T. 22 N., R. 10 W., gauged at 44 million cubic feet and 1210 pounds pressure,

Lloyd Harris et al., Giles No. 1 in sec 34, T. 23 N., R. 11 W., Raymond et al., Jordan & Young No. 1 in sec. 33, T. 23 N., R. 10 W., and Fullilove and Wadley, Martin No. 1 in sec. 12, T. 22 N., R. 10 W., each of the last three estimated as high as 30 million cubic feet initial production.

The Giles well is plugged full of cement, the Jordan and Young has the drill stem in the hole, but the Martin and the Mayfield will probably be connected by pipe line with the Haynesville oil field, and the Munn has been supplying gas for fuel at Haynesville for several months. The wells may be classed as dry gassers although the Mayfield sprayed a little oil having a gravity of 29.7 Baume and containing 6 per cent. basic sediment and water.

Production comes from the Blossom sand of the Upper Cretaceous, which is the pay sand in the Haynesville oil pool 5 miles to the east.

The total depth of the gas wells ranges from 2650 to 2750 feet and the structure is only 10 feet higher than at Haynesville, according to present development. It seems improbable that the Webster Parish structure is a continuous part of the Haynesville fold, though both appear to be high parts of a long low fold extending eastward from the northeast base of the Sabine Uplift. The sand so far drilled ranges from 2 to 18 feet thick. It is generally finely granular, calcareous, and soft. As at Haynesville, the top of the structure is surprisingly low as compared with nearby pools. It is 800 feet lower than the Homer dome 15 miles to the southeast and 1400 feet lower than the Bellevue dome 20 miles south.

The area enclosed by the five gassers is 11 miles long and 4 miles wide and contains no failures in drilling. The surface is partly hilly, partly bayou bottom land, ranging in age from the Claiborne ferruginous sands and clays of the Tertiary to similar formations of the Quaternary. Surface dips in the Eocene are only indefinitely representative of subsurface structure 2700 below it in the Upper Cretaceous.

The pool is not at all clearly defined, although several salt water holes have been drilled to the southeast within 2 or 3 miles of the gas wells. Salt water has also been encountered four miles to the northwest and four miles to the northeast. Present development indicates a gas pool 11 miles long, east and west, across the north end of the parish. This long fold appears to have a productive structural relief of 40 feet, below which salt water occurs. Oil has been found near the salt water line in encouraging quantity, but no oil producers have been made because of proximity to salt water down the structure. . There will be an active drilling campaign in northern Webster this summer.

Shreveport, Louisiana, J. P. D. Hull.
April 15, 1922.

A NEW GULF COAST SALT DOME

About the first of April it became defiinitely established and generally known that Wheat No. 1 drilling jointly by Gulf Production Company and Snowden Brothers & McSweeney, on Wheat Ranch, 8 miles south

of the town of Richmond, Ford Bend County, Texas, had penetrated salt dome materials at a depth of less than 700 feet. Thus a hitherto unknown or unproven salt dome is discovered and may now be added to the list of previously known Gulf Coast domes. Similarly a new potential oil field is indicated for as yet no proven salt dome on the Gulf Coast can be eliminated positively from the ranks of petroleum producing possibilities. In the case of the new dome petroleum has, as a matter of fact, been encountered in the "cap rock" although probably not in commercial quantity at the present shallow depth. The oil is 22° B. in gravity, similar to the ordinary Gulf Coast product.

Although the locality is one in which the presence of a salt dome might well be suspected, since it is on a line with Damon Mound and West Columbia and at a logical distance north of Damon Mound, yet the surface evidences of this new dome are meager and have failed to impress a number of careful students of salt domes who have examined them. There is no topographic evidence of uplift nor any solution depression—characters which are common to known salt domes. Big Creek, a stream of secondary importance, flows southward past the well and across the probable top of the dome, but the general area is a high inter-stream divide extending about north and south between San Bernard and Brazos rivers.

Along Big Creek near the new well are several seeps of inflammable gas with small springs of mineralized water. Both gas and water yield an odor of hydrogen sulphide. Larger and more active gas seeps with similar "sulphur water" springs elsewhere in the Gulf Coast country have, on several occasions in the past, led to drilling exploration which failed to find either salt-domes or petroleum. An old water well less than 100 feet deep near the site of the discovery well yielded water charged with hydrogen sulphide, and it is alleged to have been drilled through an unusual amount of rock. The discovery well is said to have drilled in rock almost continuously from the surface to the present depth indicating a degree of induration which is rarely encountered in the Gulf Coast formations except over salt domes.

Credit for the discovery goes most appropriately to Mr. L. P. Garrett, Chief Geologist for Gulf Production Company, upon whose judgement the decision to drill this prospect and the location for the first well were made. Messrs. Sorelle & Meyer, Houston Brokers, blocked the acreage around the gas seeps and turned it over to Gulf Production Company and Snowden Brothers & McSweeney, jointly. The decision for Snowden Brothers & McSweeney to participate in this undertaking rested with Mr. J. P. Shannon, Supt., who also drilled the discovery well at Pierce Junction last year, on his first venture into the Gulf Coast fields. Mr. Lee Hager, a prominent Houston geologist, also realized the significance of the surface showings in the vicinity of the new discovery as is evidenced by the facts that several years ago he purchased something over 600 acres of fee land around the gas seeps and that he still retains his royalty interest in this land.

In spite of the foregoing statement that all Gulf Coast salt domes are possible future oil fields, and in spite of the showing of oil in the discovery well it would be incorrect to assume that the dome just discovered in Fort Bend County, (which might well be called the Big Creek Dome), is certainly and speedily to become the site of a new oil field. If the cap rock fails to produce commercially and exploration of lateral sands around the periphery of the dome becomes necessary before production is obtained, the search, even though ultimately successful, will probably require a period of years of preliminary drilling. After all, less than half of our known salt domes are commercially productive of petroleum, and the new discovery although certainly a salt dome may or may not develop into an oil field.

Houston, Texas. WALLACE E. PRATT.

On May 15 Wheat No. 1 had been completed at 710 feet in salt and was rated as a 100-barrel pumper. W. E. P.

A SCHEDULE FOR THE FIELD DESCRIPTION OF SEDIMENTARY ROCKS

A schedule for the field description of sedimentary rocks has just been prepared by a subcommittee of the Committee on Sedimentation of the National Research Council.

The object is to furnish a check list to aid the field description of sedimentary rocks. It is not intended to indicate what are the most important characters to describe but to present an outline broad enough to cover any special case, yet of such size that the printed form can be pasted in the back of a note book. Theoretically of course such an ideal is quite unattainable. The characters which could be recognized in any sedimentary rock are numberless, and all that a schedule like this does is to formulate the points of view and the problems that appear uppermost at the time.

What is true of the wide range of characters to be observed, is even more true of the relations of characters. These are necessarily more numerous than the characters, and their determination much more important; for most if not all of the progress of knowledge is based essentially on the discovery of new relations between facts. While the user of the schedule should be reminded constantly to look for relationships, the impression should be avoided that in this or any other respect the schedule may be relied on as final or complete. All it aims to do is to serve as a guide to those less familiar with the subject and as a systematic jog to the memory of the more experienced.

An attempt has been made to prepare this schedule in such form that it would be applicable to any part of a stratagraphic section from all of an extensive exposure down to the minutest lamina or lenticle. In practice it is generally best to begin by determining the largest lithologic divisions, according to the judgment of the observer, of an exposure as a whole, and recording their characters, following the sched-

ule as far as it can be applied. Then subdivisions of the next order should be determined and described, and so on down to the smallest units observable. This will not be so long a process as it may seem, since many characters would be observable only in the smaller divisions.

The feature in the schedule which is considered most important and fundamental is the emphasis on quantitative results. It is not intended to encourage a super-refinement beyond the needs of the investigator. In very many cases a mere quantitative estimate will suffice, but in the great majority of cases quantitative results are the only ones that can be reworked in the office by the geologist himself or permit of new interpretation by others. To build up a permanent record for the future, therefore, quantitative data are essential.

Underlying any system for the description of sedimentary rocks must be some system of classification of the characters to be described, but in a practical system it is necessary to avoid a philosophically rigid and perfect a system which might be so abstract as not to be readily applied.

An important feature of field work which does not belong in the schedule is the collection of specimens for laboratory study. Any material collected for laboratory study should probably serve one of three purposes: (a) To form part of a complete series representing every bed or what appears to the collector to be every distinct type of rock, (b) To represent some peculiar type of rock which the collector can not sufficiently identify in the field, or which he recognizes to be new, and (c) To help in the testing of hypotheses formed in the field as to the origin of the characters of any rock. In general, specimens should not be picked up hastily here and there in the hope that laboratory study, unsupported by careful field study and hypotheses, may reveal their origin.

Among suggestions which the committee received but which are not incorporated in the schedule, the largest number concerned secondary features or what might be called the indirect expressions of the features of the rock. In formulating the purpose of the schedule it was decided as desirable to make it bring out only those features which might ultimately serve to determine the conditions under which the rock was formed, features acquired later (epigenetic) being considered only with a view to disentangling them from the original features. Such things as jointing, disturbance and distortion of beds by movement subsequent to burial, slickensiding, erosion forms, weathering, color banding by ground waters, topographic and vegetational expression of lithology were omitted, as they do not fall within this purpose. Any of them may be expressions of the primary characteristics of the rocks but are significant for the purpose only in so far as the characteristics they express can be directly determined. Though they may therefore be of use to the geologist in the field, as a clue to certain physical features he should look for, they may be excluded from consideration as ultimate in the description which is in mind.

Moreover, it is evident that if one starts out to use such features it would soon be necessary to prepare a schedule for the whole range of field work including tectonics, igneous geology, physiography and physiographic processes, ground water, etc.

With the above formulation of the object of the schedule in mind the committee hesitated for some time over the question of describing *shaly structure*. The final conclusion was that it is not known to what shaly structure is due—whether to the manner in which the shale bed was deposited or to forces to which it has since been subjected—and that until this is decided it would not only be justifiable to include it in the schedule but that in so doing it might be possible to help solve the problem of the origin of shaly structure. Users of this schedule are therefore urged to pay special attention to this problem, and it would be very desirable for observers to send to the committee any material that illustrates their conception of shale or that seems to throw any light on the origin of shaly structure. It has been placed under *C. 1.*, where it belongs if it belongs in the schedule at all.

Color is a property that is listed in several places in the schedule. The need for some accurate and generally accepted method of describing color is keenly felt by geologists—that it is, in fact, the part of the schedule as planned which has received the heartiest welcome.

Elements of the problems of color standardization are very clearly and simply presented in Technologic Paper 167 of the U. S. Bureau of Standards, "An examination of the Munsell color system," by Irwin G. Priest, K. S. Gibson, and H. J. McNicholas, which may be had from the Superintendent of Documents, Washington, D. C., for 10 cents. This paper makes it evident that years will probably be consumed in the merely mechanical work of standardizing the entire color scale, but Mr. Priest, the senior author of the paper, has approved the use in the meantime of some of th less perfect systems, such as that of Robert Ridgway, "Color standards and color nomenclature," published by the author at Washington, D. C., in 1912 and for sale by A. Hoen & Co., Chester, Chase, and Biddle Streets, Baltimore, Md., or the Munsell system, descsibed by A. H. Munsell in "A color notation" and represented in the "Atlas of the Munsell color system," Munsell Color Co., Printing Crafts Building, 8th Ave. & 34 St. New York City. The positions in the final color system of the colors in these systems can be determined when the final system is established, and thus all color descriptions based on them can be related to the final system. It is hoped soon to prepare a set of colors small enough to be mounted in a field notebook, and in submitting that its use will be discussed somewhat more fully.

Discussion of the preliminary schedule brought out the fact that abstractly divisions *C.2* and *C.4* of the schedule differ only in the scale of the characters dealt with, but as this difference in scale indicates definite geologic distinction it has been allowed to stand.

In subdivision D. *1.* c quantitative methods have been recommended for

measuring the shape of the larger constituents of sedimentary rocks, mainly pebbles and larger fragments. These methods are based on the work of C. K. Wentworth, reported in preliminary form at the meeting of the Geological Society of America (see abstract in Bull. Geol. Soc. America, vol. 32, No. 1, p. 89, 1921) and to be published in greater detail as Bulletin 730-C of the U. S. Geological Survey. Although Mr. Wentworth has devised instruments for making these measurements, a consultation with him showed that it is possible to make rather accurate estimates of the dimensions to be determined. Though the selection of dimensions to be measured is only preliminary and will probably be modified and improved by Mr. Wentworth and others, his system is recommended as by far the best and most precise now available.

The schedule is not regarded by the Committee as in any way final. The experience of those who use it in the field and new discoveries or changes in the leading problems of the subject are bound to call for modifications which will make new editions of the schedule necessary; and suggestions to this end will be welcome. Such suggestions should be sent to the chairman of the subcommittee, Dr. Marcus I. Goldman, U. S. Geological Survey, Washington, D. C.

Copies of the schedule in convenient size (5 by 8 inches) for use in notebook may be obtained on application to Dr. Goldman.

A Schedule for the Field Description of Sedimentary Rocks.

A. *External form of the rock unit.* Lenticular, persistent, very regular in thickness, etc.; dimensions.

B. *Color.* Color of unit as a whole, wet or dry, according to Ridgway or Munsell color system, or color card of this committee.

C. *Bedding.*

1. How manifested: Sharp, by partings, by difference in texture, color, etc.; transitional; shaly (see introductory note).

2. Shape of bedding surfaces: plane, undulating, ripple-marked, etc.; irregular; if not plane, give details of form and dimensions of features.

3. Thickness of beds: Comparative thickness; different orders. Relation of thickness; rhythmic; random. If variable, relation between thickness and composition, bedding, etc.

4. Attitude and direction of bedding surfaces: Horizontal, inclined, curved. Relation to each other: Parallel, intersecting, tangential; angles between different attitudes and directions; dip, strikes; dimensions; relation of size, composition, shape, etc., to attitude and direction; relation of composition to different types of bedding.

5. Marking of bedding surfaces: Mud cracks, rain prints, bubble impressions, ice-crystal impressions, trails, footprints, etc.

6. Disturbances of bedding: Edgewise or intraformational conglomerates, folding or crumpling of individual beds before consolidation, etc.

D. *Composition.*

1. Inorganic constituents.

a. Mineralogy or lithology of principal constituents.

b. Size: Prevailing size if fairly uniform; range in sizes if not; proportions of different sizes as determined by sieving where feasible; distribution of sizes with relation to other features; vertical and lateral variations in size.

c. Shape: Crystalline (automorphic), angular, subangular, subrounded, rounded; relation of shape to size, material, position in beds, etc. For quantitative results on pebbles, etc., estimate or measure radius of curvature of sharpest edge, mean radius, and maximum and minimum diameter.

d. Character of surface: Glossy, smooth, mat, pitted, chatter marked, etc.

e. Orientation: With respect to bedding; with respect to life dimensions with respect to bedding to each other, etc.

f. Chemical and internal physical condition: Fresh, weathered, decomposed, cracked, etc.

g. Packing: Closeness and manner.

h. Pore space.

i. Cement: Present or absent; proportion; composition; variations in composition vertically and laterally and in relation to other characters; disposition with respect to bedding, fractures, etc.

j. Color: Wet or dry; location, inherent or as a stain in constituents or cement; variations and their relation to other factors, as composition, porosity, bedding, fracturing, fossils.

2. Organic constituents.

a. Kinds.

b. Size: Does the distribution of sizes show effect of mechanical deposition?

c. Condition: Entire, fragmented, partly dissolved, etc. Relation to kinds.

d. Distribution: With respect to character of beds, kinds of organisms, bedding, evidence of burrowing, etc.
habits, possible manner of death, etc.

e. Orientation: With respect to bedding; with respect to life

E. *Concretions.*

1. Form, size, color, composition, and their variations.

2. Internal structure; central nucleus organic or inorganic; central hollow; homogeneous; banded horizontally, concentrically, etc.; radial; compact; vesicular.

3. Boundary against country rock: Sharp, transitional with or without change in character.

4. Relation of bedding to concretions: Continuous through concretions, deflected above, below, or both; thinned above, below, etc.

5. Distribution: Random; regular; if regular, intervals between groups (layers), vertically and horizontally; differences between characters of concretions in different groups (layers). Relation of distribution to other characters, as mechanical, chemical, or organic composition of country rock; jointing, fissuring, folding, etc., of country rock; topography; ground-water level; etc.

Note.—Define all terms that might be at all uncertain. Use metric units if possible. Describe first the largest units recognized, then those of the next order. and so on down to the smallest.

NOTE ON "A REVIEW OF OIL AND GAS POOLS IN NORTH LOUISIANA TERRITORY" BY J. P. D. HULL AND W. C. SPOONER.

WALLACE E. PRATT: Mr. Washburne has suggested that the anhydrite in the Lower Cretaceous rocks at Pine Island which Mr. Hull has described has heretofore not been recognized as a possible original source of the salt of our Gulf Coast salt domes. I should like to recall the fact that Dr. E. T. Dumble has previously recognized the gypsum-anhydrite horizon of the Lower Cretaceous as a possible source of the salt in the salt domes of the Gulf Coast, although I cannot make exact reference to the publication.

REVIEWS AND NEW PUBLICATIONS

HANDBOOK FOR FIELD GEOLOGISTS: By C. W. Hayes and Sidney Paige John Wiley & Sons, Inc. The third edition of this well known handbook has been thoroughly revised by Sidney Paige. It contains 166 pages and is sold for $2.50.

A HANDBOOK OF THE PETROLEUM INDUSTRY: By David T. Day and others. John Wiley & Sons Inc. This treatise on the petroleum industry is the work of twenty contributors and will be published in May.

MAP OF WEST VIRGINIA: A new edition of the map of West Virginia by the West Virginia Geological Survey, Morgantown, W. Va., scale 8 miles to one inch is purchasable for $1.00. It shows the location of coal, gas, limestone, and iron ore deposits.

PETROLEUM ENGINEERING IN THE BURKBURNETT FIELD, TEXAS: By H. W. Bell and J. B. Kerr, of the U. S. Bureau of Mines. This report of the Bureau of Mines is being published in the weekly numbers of the Oil and Gas Journal commencing March 24th. The majority of the reports of the Bureau of Mines are published by Chambers of Commerce, Conservation Commissions, and in various trade journals. Government work is supposed to be done for the benefit of all citizens and taxpayers and it is very doubtful if even interested geologists can learn of these various publications without keeping in constant communication with the branch offices of the Bureau.

A TREATISE ON PETROLEUM: By Sir Boverton Redwood, J. B. Lippincott Co. The fourth edition of this valuable work has been published with the co-operation of the U. S. Geological Survey and of many other institutions and individuals. The cost is $39.00. Mr. O. B. Hopkins was one of the chief contributors for the Geological Survey. The three volumes including index and extensive bibliography comprise 1,368 pages.

MAPS OF SLICK AND LYONS-QUINN-DEANAR FIELDS: The Chamber of Commerce, Bartlesville, Okla., has published production maps of the Slick field and of the Lyons, Quinn- Deaner fields which are white paper prints with blue lines. The elevation of wells in the Slick field are given, but no data except the location of the wells in T. 11 N., R. 11 E. The cost of the maps is 25c each. A report on the Slick field in 7. 15-16 N., R. 10 E., is in preparation.

Brady, G. S. The Mendoza-Neuquen petroleum fields. Commerce Reports, Bureau of Foreign and Domestic Commerce, March 6, 1922, pp. 573-574. Gives location of the fields, characteristics of the oil, account of present operations, and brief discussion of possibilities of the fields.

Clements, J. M. Japan preparing to test areas considered possible oil bearing. Nat. Petroleum News, vo.l 14, Mtr. 1, 1922, pp 48-0-48-P. Brief description of Japan's known fields, production statistics, and estimate of oil reserves.

Cronshaw, H. B. Petroleum. London, John Murray, 1921. 110 pp. Monograph prepared under the direction of the Mineral Resources Committee of the Imperial Institute. Review of the world's petroleum resources with particular reference to the British Empire and prospects of development in regions still unexplored. Introductory chapter deals with the characteristics, occurrence, mining, refining and uses of petroleum. Gives statistics of production for the principal producing countries, small oil-field map of the world, and brief bibliography on petroleum.

Jillson, W. R. Conservation of natural gas in Kentucky, Louisville, Ky., John P. Morton & Company, 1922. 152 pp. Describes the natural gas-resources and by-product industries of Kentucky, giving statistics of production, and discuss the causes of waste of natural gas and the necessity for immediate conservation. Closes with a brief selected bibliography on the production, utilization, and conservation of natural gas.

Marsters, V. F. Peru far below production that might be developed. Nat. Petroleum News, vol, 14, Mar. 1, 1922, pp. 48G-48I. Gives history of the industry in Peru, details of development in each field, production statistics and discussion of possible future production. Also reviews possibilities in Ecuador.

Ness, J. Canada's northern oilfields. Oildom, vol. 13, March 1922 pp. 43-51. Paper before the third annual convention of the Natural Gas and Petroleum Association of Canada. Gives location of the fields, topography and natural resources, geology, occurrence of petroleum and discussion of future prospects.

Arnold, Ralph and English, Walter. Canada's hope for oil lies in Western Provinces, not in far north. Nat. Petroleum News, vol, 14, Mar. 1, 1922, p. 48C. Gives estimates for five areas of Canada made by comparing them to geologically similar districts in the United States where development has been sufficient to prove fairly definitely what the ulimate resources will be.

Benson, W. N. An outline of the geology of New Zealand. Jour. Geol., vol. 30, Jan-Feb. 1922, pp. 1-17. Based on the writer's presidential address before the geological section of the Australian Association for the Advancement of Science, 1921.

Blackwelder, Eliot. Meager data on China and Siberia not promising from oil standpoint. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48P-48R. Discusses possibilities in these countries.

Branner, J. C. Brazil is territory untested and little known geologically. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48-I-48J. Describes petroleum indications in Brazil and discusses possibilities.

De Golyer, E. On the estimating of petroleum reserves. Econ. Geol., vol. 17, Jan-Feb, 1922, pp. 40-45. On the value and reliability of such estimates.

Dod, H. C. Petroleum in Victoria. Ind. Australian and Mining Stand., vol. 66, Dec. 8, 1921, p. 1048. Reviews structural features of this part of Australia, which are known to be favorable for oil accumulation.

Douglass, Earl. The oil problem in the Uinta Basin, Utah. Salt Lake Min. Rev., vol. 23, Nov. 30, 1921, pp. 12-13; Dec. 15, pp. 14-15; Dec. 30, pp. 9-11; Jan. 30, 1922, pp. 13-14; Feb. 28, pp. 9-11; Mar. 15, pp 11-14; to be continued

Garfias, V. R. Intelligent prospecting in Mexico vital to stability of industry. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48M, 48N.

Summarizes present conditions in the Mexican fields and discusses possibilities.

Hager, Dorsey. Oil possibilities, Holbrook area, Arizona. Mining and Oil Bull., vol. 8, Jan., 1922, pp. 23-26, 33-34; Feb, pp. 71-74, 81, 94; to be continued. Describes conditions in this field which would justify testing for oil, gives physiography of the area and gives sections showing stratigraphic relations. See also Oil and Gas Jour., vol. 20, Dec. 16, 1921, p. 76.

Howell, J. V. Some structural factors in the accumulation of oil in southwestern Oklahoma. Econ. Geol. vol. 17, Jan. Feb., 1922, pp. 15-33. Detailed study of structural relations in the region south of the Arbuckle and Wichita moutains and north of the Red River.

International Petroleum Reporter. Mining engineers urge oil reforms. Vol. 1, March 1, 1922, pp. 13-14. Resume of the petroleum symposium of the American Institute of Mining and Metallurgical Engineers in New York, February, 1922. See also Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 25-27. Oildom, vol. 13, March 1922, pp. 17-18.

Jillson, W. R. Oil and gas possibilities of "the Jackson Purchase" region. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 191-220. Gives geology of the region, results of drillings, with well logs, and summary of oil and gas possibilities.

Jillson W. R. The Sixth Geological Survey. An administrative report of the several mineral resource and general geological investigations undertaken and completed in Kentucky during the biennial period 1920-1921. Presented with ten separate miscellaneous geological papers by G. P. Merrill, Stuart Weller, W. R. Jillson, Stuart St. Clair, and Charles Stevens Crouse. Kentucky Geol. Survey, Series 6, vol. 6, 1921. 291 pp.

Kemp, J. F. and Billingsley, Paul. Sweet Grass Hills, Montana. Bull. Geol. Soc. Am., vol. 32, Dec. 1, 1921, pp. 437-478. Detailed geological study.

Killick, V. W. "It can safely be set down that any geological estimate of the world's oil resources, at this time, is entirely premature." Petroleum World (Los Angeles), vol. 7, Feb. 1922, pp. 5, 7, 20, 22, 24.

Miser, H. D. Mineral resources of the Weynesboro Quadrangle, Tennessee. Tennessee State Geol. Survey Bull. 26, 1921. 171 pp. Includes section (pp. 147-152) describing oil and gas occurrence and accumulation in the Waynesboro Quadrangle and discussing possibilities.

Moffit, F. H. Geology of the vicinity of Tuxedni Bay, Cook Inlet, Alaska. U. S. Geol. Survey Bull. 722-D, 1921. 7 pp. Results of a study with particular reference to oil possibilities in this region.

Moore, R. C. and Plummer, F. B. Pennsylvanian stratigraphy of north-central Texas. Jour. Geol. vol. 30, Jan.-Feb. 1922, pp. 18-42. See also under Plummer, F. B. and Moore, R. C.

Nelson, W. A. Description of oil and gas areas in Tennessee and con ditions affecting new areas. Tennessee State Geol. Survey Bull. 25, 1921, (Administrative report of the State Geologist, 1920) pp. 49-66. Paper before the American Association of Petroleum Geologists, Mar. 1921.

Nelson, W. A. Report on the geology and structural features of Benton County as they affect oil and gas possibilities. Tennessee State Geological Survey Bull. 25, 1921, (Administrative Report of the State Geologist, 1920) pp. 41-45.

Park, James. Geology and mineral resources of Western Southland. New Zealand Dept. Mines, Geol. Survey Branch, Bull. 23, new series, Wellington, 1921, 88 pp. Detailed geological study, including discussion of oil prospects.

Petroleum World (London). Oil and gas in western Canada. Vol. 19, March, 1922, pp. 100-103. Shows "from the similarity of geological conditions in Alberta and other parts of western Canada to the usual conditions accompanying the hydrocarbons throughout the world, that great possibilities await the exploiters of petroleum and natural gas in the western fields."

Plummer, F. B. and Moore, R. C. Stratigraphy of the Pennsylvanian formations of north-central Texas. Univ. Texas Bull. 2132, June 5. 1921, 237 pp. Maps and plates. Based on studies primarily concerned with the possible development of oil and gas in the North Texas Pennsylvanian area.

Powers, Sidney. Solitario uplift, Presidio-Brewster counties, Texas. Bull. Geol. Soc. Am., vol. 32, Dec. 1, 1921, pp. 417-428. Regional geology, detailed geology, and discussion of origin of the dome.

Pratt, W. E. Philippine Islands may be classed as possible oil bearing territory. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48J, 48L. Gives location of known seepages and indications of oil and discusses possibilities.

Redfield, A. H. Central America too little known to afford estimate of possibilities. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48B, 48D. Estimation of the unmined petroleum reserves of Central America by comparison, as far as possible, of the structure of the unknown reserves with that of a supposedly analogous North American field whose reserves have been estimated.

Redfield, A. H. West Indies may be considered to hold little deposits of oil. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48E, 48F. Gives location of some promising areas and known structural characteristics of the islands, but states that on account of the lack of details of local geology satisfactory estimates are impossible.

Robinson, H. M. Geologic structure and oil and gas prospects of a part of Jefferson County, Okla. U. S. Geol. Survey Bull. 726 F, 1921, 26 pp. Gives stratigraphy and structure of the area and suggestions to prospectors.

St. Clair, Stuart. The oil pools of Warren County, Kentucky. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 103-148. Gives history of development, geology of the oil fields, occurrence and source of the oil, well records, and discussion of economic considerations.

Scott, W. W. and Stroud, B. K. The Haynesville oil field, Claiborne Parish Louisiana. Louisiana Dept. of Conservation, Bull. No. 11, Jan. 1922. 26 pp. In co-operation with the U. S. Bureau of Mines. Deals with the underground conditions and methods of operating in this field, the purpose of the report being primarily to aid the operators in their development problems, especially those encountered during the drilling of the wells.

Stalder, Walter. The Ciervo anticlinal bow oil field of California. Eng. and Min. Jour., vol, 113, Mar. 11, 1922, pp. 409-413. Details of a geological study of a prospective field on the West side of the San Joaquin Valley.

Vander Leck, Lawrence. Petroleum resources of California. California State Mining Bureau Bull. 89, 1921. 179 pp. Report written to

"take stock of the oil resources of the State and in particular to determine, if possible, the opportunity that exists for extending the productive area into districts that have hitherto been regarded as unfavorable." Gives general theory of the origin and accumulation of oil in California, description of the oil-bearing formations in the State and detailed discussion of possibilities in various areas.

Wagner, Paul. Oil in sight from Mexico's known fields 225 million. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 57-59. Reviews possibilities south and southwest of Tampico.

Wagner, Paul. Tehuantepec believed to be important field for future production. Nat. Petroleum News, vol. 14, March 1, 1922, pp. 39-40, 43. Brief description of geologic structure of the Isthmian fields, account of development and discussion of possibilities.

Washburne, C. W. and White, K. D. Colombia's possible oil fields extend over enormous territory. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48K-48L. Gives history and present state of development in Colombia and discusses possibilities.

Weller, Stuart. Oil and gas possibilities in Caldwell County, Kentucky. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 221-231. Gives stratigraphy and structure, summary of drilling and discussion of possibilities.

Ambrose, A. W. Problems in developing prospects. Internat. Petroleum Rep., vol. 1, Feb. 15, 1922, pp. 11-12. Paper before the Pan-American Petroleum Conference, Washington, Feb. 7, 1922. Discusses problems of drilling and production, transportation and storage, and refining of oil in the development of new fields. See also Oil and Gas Jour., vol. 20, Feb. 17, 1922, p. 6 Oil Age, vol. 18, March, 1922, p. 25. Oildom, vol. 13, March, 1922, pp. 35-36. Oil Field Eng., vol. 24, Feb. 1922, p. 56.

California State Mining Bureau. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921. 52 pp. Contains, in addition to the summary of operations in the State during the month, the following articles: Notes on the use of oil instead of water or mud fluid in drilling, by H. B. Thomson. A method for loosening frozen casing or drill pipe with oil, by W. W. Copp. See under those authors.

Copp, W. W. A method for loosening frozen casing or drill pipe with oil. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921, pp. 13-15. Describes procedure and cites examples showing the successful use of the method.

Edson, F. A. Diamond drilling in oil production. Oil and Gas Jour., vol. 20, Mar. 10, 1922, pp. 90-92. Describes outfit, its use and advantages.

Fell, D. A. Oil shale and a future American industry. Railroad Red Book, vol. 39, Feb. 1922, pp. 379-382. Reprinted from Financial Year Book, Daily Commercial News, San Francisco, Cal., Sept., 1921, pp. 96-97. On the possibilities of the American industry and general methods of mining, retorting and refining, particularly those used in Australia at the present time.

Gray, Alexander. Oil exploration. Canadian Min. Jour., vol. 43, Feb. 3, 1922, pp. 68-70. Review of Canadian oil problems and status of new development.

Jillson, W. R. A new method of producing crude oil in Kentucky. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 149-154. Describes "oil mining" methods used in Estill County, Kentucky, where a shaft has been sunk and oil produced from it.

Kessal, H. F. Conditioning a well for oil production. Ind. Australian and Mining Stand., vol. 66, Dec. 22, 1921, pp. 1135-1136; to be continued. Discusses the effect of the presence of water and its exclusion from oil wells.

Oil Age. Core drilling improves rotary efficiency. Vol. 18, March, 1922, p. 10. Enumerates the disadvantages of the drive-pipe and the single-barrel core drill in rotary sampling, and describes the Elliott double-barrel core drill recently perfected for this purpose, giving its advantages.

Pardo, C. W. Mexican oil production—some big wells. Texaco Star, vol. 9, Feb. 1922, pp. 5-10. Describes some of the famous large wells in Mexican fields and explains some of the difficulties of developing fields in Mexico.

Smith, L. E. Opinions still differ as to value of flooding Bradford sand. Nat. Petroleum News, vol. 14, Feb. 15, 1922, p. 67-68, 71. Discusses various phases of the subject and gives opinions of operators in the field.

Standard Oil Bulletin. A hole deep and dry. Vol. 9, Feb. 1922, pp. 14-15. An account of the drilling and abandoning of a hole in Kern County, California, which stands as the deepest to date in the State.

Thompson, H. B. Notes on the use of oil instead of water or mud fluid as a mixing fluid in drilling. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921, pp. 5-12. Discusses some of the records, both of success and failure, in the use of oil for drilling, together with the manner of overcoming the difficulties presented.

Wagner, Paul. Diamond drill may revolutionize high cost field test operations. Nat. Petroleum News, vol. 14, Mar. 8, 1922, pp. 39-40, 43, 45. On the advantages of the diamond drill in wild-catting and its successful use in Mexican fields.

THE ASSOCIATION ROUND TABLE

PROCEEDINGS OF THE SEVENTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS HELD IN OKLAHOMA CITY

March 9-11, 1922

The headquarters of the American Association of Petroleum Geologists during its Seventh Annual Meeting were at the Huckins Hotel. The technical and business sessions were held in the Elks Hall and the public lecture on Thursday evening in the Christian Church.

The first session was called to order at 10 o'clock Thursday morning by President George C. Matson. A cordial welcome and friendly greetings were extended by Charles E. Hall, Manager of the Chamber of Commerce, and by Dr. Irving Perrine, President of the Oklahoma City Geological Society. Following these greetings the papers of the regular program were presented in order.

The afternoon session on Thursday was occupied by several papers on "Production" two papers on "Diamond Drilling" and a rather extended discussion of professional ethics in petroleum geology.

On Thursday evening a pubblic illustrated lecture was given at the Christian Church by Dr. Charles Schuchert on "The General Geology of South America." After this lecture the members and friends of the association were entertained at a smoker at the rooms of the Chamber of Commerce where the members of the Oklahoma City Geological Society were the hosts for the association.

On Friday morning several excellent papers on Oklahoma and Kansas were followed by a business meeting at which the report of the Secretary Treasurer, Dr. C. E. Decker, and the Editor, Dr. Raymond C. Moore, were given. These reports will appear later in these proceedings.

Before the close of this session a Central Committee was appointed consisting of Max W. Ball, Chairman; Leon Pepperberg, Secretary; David Donogue, R. S. McFarland, A. L. Beekly, Fritz Aurin, F. W. DeWolf, K. C. Heald, Charles Taylor, W. E. Wrather, George C. Matson, W. E. Pratt, R. C. Moore, C. E. Decker.

Friday afternoon a series of excellent papers were given in a regional session on Texas, Louisiana, Mississippi, and Utah.

On Saturday morning a concluding business meeting was held at which the report of the Central Committee was made while Max W. Ball, Chairman, presided. Amendments to the constitution to define the method of election of officers, to determine the place for holding the annual meeting, to change the name of the association, constitute fellows, to drop members for non-payment of dues, and to increase the dues for associate members were not passed. Other amendments proposed to increase the requirements for associate members from twenty to thirty

hours of geology, to establish honorary membership in the association and to change the article dealing with publications so that the associate editors shall replace the members of the publication committee were adopted by the association. These changes will be submitted to a vote as required by the constitution.

Section IV of the By-Laws was amended to read as follows: "Any member who shall be guilty of flagrant violation of the established principles of professional ethics may upon the unanimous vote of the executive committee be suspended or expelled from membership provided that such person shall, before suspension or expulsion, be granted a hearing before the executive committee.

The report of the Resolutions Committee was read and this report will be found in the latter part of these proceedings.

In the election of officers for the ensuing year two nominations were made for president, D. W. Ohern and W. E. Wrather, the latter being elected for the presidency. Max W. Ball was the only nominee for Vice-President and Charles E. Decker and Raymond C. Moore were reelected respectively to the offices of secretary-treasurer and editor.

The technical sessions of the association were continued the rest of the forenoon and into the afternoon with a number of interesting illustrated papers which provoked extended discussion, particularly the one on China and a structural paper.

Besides the smoker on Thursday evening the main social event was the annual dinner Friday evening at the Huckins Hotel with Dr. D. W. Ohern as toastmaster, and Dr. Charles Schuchert, Dr. J. B. Umpleby, Mrs. W. C. Kite and Mr. James Gardner as speakers. A violin solo was rendered by Mrs Frank Buttram.

The visiting ladies were entertained by a musicale at Mrs. Frank Buttram's, a line party at the theatre and an automobile tour about the city.

The reports of the Committee on Resolutions, the officers of the association, and the members of the standing committees for the coming year are given below.

The Committee on Resolutions presented the following report, which was adopted.

Resolution from Visiting Ladies.

The visiting ladies wish to thank the members of the local geological society and their wives for the many courtesies extended and the delightful entertainment provided, and take this opportunity of expressing their appreciation.

Respectfully submitted,
MRS. A. W. MCCOY,
MRS. C. E. DECKER,
Committee.

A general resolution was passed with reference to our officials at Washington, D. C., endorsing a continued increase in the activities of the Departments of State and Commerce with respect to the international petroleum situation.

Respectfully submitted,
A. C. VEATCH,
RALPH ARNOLD,
WALLACE PRATT,
International Relations Committee

After C. W. Washburne announced the establishment of the medal, the following resolution presented by Max W. Ball, was passed:

That thhe American Association of Petroleum Geologists endorse the movement of the American Institute of Mining and Metallurgical Engineers to estalish a medal commemorating the discovery of the Gulf Coast oil region by Captain Anthony F. Lucas at Spindletop, Texas, on January 10, 1901; said medal to be granted on suitable occasions, for the most note-worthy contribution to the knowledge of oil fields or to methods of producing oil.

A resoultion was passed disapproving short course schools advertising to prepare men for work as petroleum geologists in a few months.

Resolutions of Appreciation

Whereas a large part of the great success of this meeting is due to the thorough hospitality and untiring efforts of the Chamber of Commerce, the members of the Oklahoma City Geological Society, and their wives.

Now therefore, be it resolved, that the association express its great appreciation and gratitude for the many kindnesses and courtesies extended, and that suitable copies of this resolution be sent to those mentioned above.

Respectfully submitted,
S. POWERS, *Chairman.*
F. H. LAHEE,
D. DONOGHUE,
Committee.

The following committees were appointed:

ASSOCIATE EDITORS

Ralph Arnold, Los Angeles, California, *Pacific Coast.*
J. H. Hance, Urbana, Illinois, *Central Western.*
K. C. Heald, Washington, D. C., *General.*
R. H. Johnson, Pittsburgh, Pennsylvania, *Appalachian.*
F. H. Lahee, Dallas, Texas, *South Mid-Continent.*
Sidney Powers, Tulsa, Oklahoma, *North Mid-Continent.*
Wallace E. Pratt, Houston, Texas, *Gulf Coast.*
J. P. D. Hull, Shreveport, Louisiana, *Louisiana.*

CONSTITUTION COMMITTEE

C. W. Washburne, New York, N. Y.; F. W. Clapp, New York, N. Y.; W. E. Pratt, Houston, Texas; J. H. Gardner, Tulsa, Oklahoma.

MEMBERSHIP COMMITTEE

Ransom E. Somers, Pittsburgh, Pennsylvania, *Appalachian Division.*
Frank W. DeWolf, Urbana, Illinois, *Central Western Division.*
Richard Hughes, Tulsa, Oklahoma, *North Mid-Continent.*
Frederick H. Lahee, Dallas, Texas, *South Mid-Continent.*
Eugene Holman, Shreveport, Louisiana, *Gulf Coast Division.*
C. T. Lupton, Denver, Colorado, *Rocky Mountain Division.*
R. E. Collom, Berkeley, California, *Pacific Coast Division.*

ETHICS COMMITTEE

Roswell H. Johnson, Pittsburgh, Pennsylvania.
Alexander Deussen, Houston, Texas.
E. D. Nolan, San Francisco, California.

LEGISLATIVE COMMITTEE

Irving Perrine, Oklahoma City, Oklahoma.
D. W. Ohern, Oklahoma City, Oklahoma.
E. H. Sellards, Austin, Texas.

INTERNATIONAL RELATIONS COMMITTEE

A. C. Veatch, Port Washington, L. I., New York.
L. C. Donnelly, New York, N. Y.
Carl Beal, San Francisco, California.

The officers elected for the coming year are:
President, W. E. Wrather, Dallas, Texas.
Vice-President, Max W. Ball, Denver, Colorado.
Secretary-Treasurer, Charles E. Decker, Norman, Oklahoma.
Editor, Raymond C. Moore, Lawrence, Kansas.

These four together with George C. Matson, the retiring president, constitute the Executive Committee.

REPORT OF THE SECRETARY

Number of members March 15, 1919		210
Number of members March 18, 1920		392
Number of members March 15, 1921		621
Number of active members, March 8, 1922	631	
Number of associate members March 8, 1922	136	
Total number of members March 8, 1922		767
Applicants elected, dues still unpaid		36
Number of applications on hand		25
Number of members withdrawn		3
Number of memebrs died		1
Number of members dropped, no clue to residence		2
Number of members dropped, non-payment of dues, 2 years		7
Full members in arrears 1921 dues		24

Associate members in arrears 1921 dues.. 8
Full members in arrears 1922 dues.......................................232
Associate members in arrears 1922 dues................................ 61
Total members in arrears 1922 dues..293

Respectfully submitted,
CHARLES E. DECKER,
Secretary.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
REPORT OF TREASURER
March 10, 1922

Balance in bank March 17, 1921			$3,582.41
Received at Tulsa, from smoker and banquet			1,070.54
Receipts from annual dues			
Associates 1920		Active $ 50.00	
Associates 1921	$462.00	Active 2,302.00	
Associates 1922	440.00	Active 3,918.61	
	$902.00	$6,270.61	
Total receipts from dues			7,172.61
Receipts from sale of bulletins			
Volume I 1917	$234.25		
Volume II 1918	228.25		
Volume III 1919	367.35		
Voulme IV 1920	530.50		
Volume V 1921	612.90		
Volume VI 1922	471.59		
Total receipts from sale of bulletins			2,444.84
Receipts from separates			105.09
Interest on money in savings account			97.41
Unclassified receipts			33.35
Total receipts from all sources			14,596.25
Disbursements			
Expense of Tulsa meeting			
Badges	$ 27.53		
Programs	18.50		
Reporter	35.00		
Smoker	171.00		
Dinner	825.00		
Local Bill	100		
			1,177.03
Cost of Bulletins			
Printing (Parts I-IV)		$2,931.99	
Engraving		561.20	
Mailing		111.03	3,604.22

Salaries		
Editor	$600.00	
Secretary-Treasurer	600.00	
Stenographers	267.60	
Mailing assistant	5.50	1,473.10
Supplies ad printing (typewriter, filing case, etc.)		473.92
Postage		200.00
Cost of separates		153.63
Protested checks		68.00
Badges for Oklahoma City meeting		27.51
Drayage, express and freight		24.61
Exchange and refunds		7.80
Telephone and telegraph messages		5.01
Total disbursements		$7,214.83
Balance in savings account		5,597.41
Balance in open account		1,733.54
		$14,545.78
Outstanding checks		39.53
		$14,506.25

Respectfully submitted,
CHARLES E. DECKER,
Treasurer.

ELECTION OF OFFICERS

The following quotations from the address, on January 10th, of J. E. Spurr, retiring president of the Mining and Metallurgical Society, may be of interest to those considering the organization of the Association.

"The constitution of the Mining and Metallurgical Society as drafted was a very democratic one. It provided that all official ballots for officers should contain not fewer than two names; and that these names should be determined by a direct primary vote of all the members, giving the Council the right of nomination only when the primary vote did not result in as many as 11 votes for any executive office or in seven votes for a councillor. This was in contrast with the methods of the Institute, where there existed, and still exists, the practice of putting only one candidate for each important office on the official ballot, which is sent to each member with the grave request to vote for one out of one; where the succession of dynasty is determined by a very small and more or less permanent group; and where the membership at large has no direct vote in any matter of importance,—where, in other words, the form of government is that of a self-perpetuating oligarchy. Although provision is made for an alternative ticket at the instance of a certain number of members, such a rump ticket is rarely put in the field, which is a pity

when it is considered how largely this contributes to the joy of living, as in the well-remembered real election contest of Moore vs. Jennings.

* * * *

"The founders of the Mining and Metallurgical Society went further in their democratic constitution and provided that the council should be subject at any time to a test vote of confidence by the members, on request of 20 per cent of the membership, or two-fifths of the Council; and that in case of an adverse vote the whole Council should resign, and give way to a newly elected body. This part of the law has never been appealed to, but it puts the whole conduct of the Society in the hands of the members at any time they may choose to exercise the control.

"The constitution also provided that the Society could take no action on any matter of policy, except by a referendum or popular vote of its members, and this principle has been rigidly adhered to."

New York,
March 21, 1922. CHESTER W. WASHBURNE.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

FOR FULL MEMBERSHIP:

Everett S. Shaw, Denver, Colorado.
Carrol H. Wegemann
Clarence B. Osborne
Thos. S. Harrison

Lyndon L. Foley, Minneapolis, Minnesota.
A. I. Levorsen
W. H. Emmons
Clinton R. Stauffer

Matthew J. Kirwan, Bartlesville, Oklahoma.
Sidney Powers
T. E. Swigart
L. H. White

Dilworth S. Hager, Houston, Texas.
Wallace E. Pratt
W. F. Henniger
W. E. Wrather

Dwight E. Edson, Mexia, Texas.
Wallace E. Pratt
Alexander Deussen
John R. Suman.

Walter C. Mendenhall, Chevy Chase, Maryland.
A. E. Fath
David White
K. C. Heald

Harry W. Bell, Dallas, Texas.
John B. Kerr
V. V. Waite
Leon J. Pepperberg

William G. Barrett, Williamstown, Ontario, Can.
D. D. Condit
J. K. Knox
D. E. Lounsbery

Walter Stadler, Oakland, California.
R. P. McLaughlin
R. E. Collom
Charles L. Baker

Richard A. Smith, Lansing, Mich.
Oren F. Evans
R. W. Clark
C. W. Shannon

Anthony Folger, Berkeley, Calif.
G. C. Gester
S. H. Gester
E. D. Nolan

Erwin A. Froyd, Denver, Colorado.
Clarence B. Osborne
Carroll H. Wegemann

Wilber I. Robinson, Lansing, Mich.
Charles Schuchert
R. W. Clark
Alan M. Bateman

Andrew N. Mackenzie, Pasadena, Calif.
Geo. C. Matson
R. H. McFarland
L. C. Snider

Charles M. Nevin, Philadelphia, Pa.
Bryan Henden
V. E. Monnett
C. E. Decker

Coler A. Yoakam, Eureka, Kansas.
U. B. Hughes
V. V. Waite
Ed W. Owen

Edward B. Wilson, Riverside, Calif.
V. V. Waite
Chas. H. Taylor
B. B. Whitehead
Richard T. Lyons, Tulsa, Oklahoma.
John A. Udden
F. H. Lahee
A. W. Duston
John W. McKim, Casper, Wyoming.
Charles T. Lupton
Lisle R. VanBurgh
C. B. Osborne
Emile Huguenin, Bakersfield, Calif.
Ralph Arnold
R. P. McLaughlin
R. E. Collom
Dr. Albert D. Brokaw, 120 Broadway, New York, N. Y.
A. H. Garner
H. H. McKee
R. C. Moore
George W. Adams, Emerson, Arkansas.
John L. Rich
George C. Matson
Clydee M. Becker
Robert S. Burg, Ft. Worth, Texas.
W. C. Bean
Frank W. Reeves
M. E. Wilson

FOR ASSOCIATE MEMBERSHIP

Homer M. Eagles, Brooklyn, New York.
R. C. Moore
Arthur Eaton
Alfred C. Bierman
Francis W. Prosser, Lawrence, Kansas.
C. E. Decker
R. C. Moore
R. S. Knappen
Reuben E. Brittain, Jr., Oklahoma City, Okla.
J. B. Umpleby
Oren F. Evans
S. Weidman
John E. Van Dall, Bartlesville, Okla.
Fred G. Rockwell
Sampel Weidman
Chas. W. Honess

Morton T. Higgs, Idabel, Oklahoma.
Alfred Gray
Ed W. Owen
U. B. Hughes
William D. Hamm, Muskogee, Oklahoma.
Walter M. Burress
A. J. Williams
S. Weidman
Joseph M. Wilson, Ft. Worth, Texas.
Frank W. Reeves
W. C. Bean
M. E. Wilson
George V. Dunn, Ponca City, Okla.
Warner Newby
Louis Franklin
E. L. Jones, Jr.
Wallace H.. Collins, Tulsa, Okla.
Charles T. Kirk
Jas. E. Hoover
John L. Howendobler
Frank B. Kelsey, San Francisco, Calif.
Stephen H. Gester
Burr McWhirt
C. B. Osborne
John P. Smoots, Shreveport, La.
Mowry Bates
A. W. Ambrose

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

LOUIS A. BARTON, of Ohio, was in Shreveport, in April, looking over Louisiana oil fields.

DONALD F. MACDONALD who returned to New York City a few months ago after almost a year in Mexico, visited Shreveport, Louisiana, and the nearby oil fields in April and has returned to New York.

HAROLD K. SHEARER was doing field work in Southern Louisiana during March and April. He has traveled considerably in Mexico and Central America the past two years.

J. M. DALE, who has been making subsurface geological maps for the Prairie Oil & Gas Co., is now with the Oklahoma Central Oil Co.

D'ARCY M. CASHIN, of the Humble Oil & Refining Co., is on the Isthmus of Tehuantepec.

JULIUS SEGALL is geologist for the ElOro Mining Co., with headquarters at Mexico City.

REVUE DE GEOLOGIE is a review of geological publications printed in English and French at the University of Liege, Liege, Belgium. The subscription price is 50 francs a year.

J. WALLACE BOSTICK has been appointed general manager of the Kansas & Gulf Co., with headquarters in the Petroleum Bldg., Tulsa.

R. W. CUMMINS represents the White Eagle Oil & Ref. Co., of Okmulgee, Oklahoma.

THE PAN-AMERICAN GEOLOGIST is a new monthly journal devoted to speculative geology, constructive geological criticism, and geological record. It is published by the Geological Publishing Co., Des Moines, Iowa, and is edited by C. R. Keyes. Subscription price it $2.50 per volume and there are two volumes a year.

CARL D. SMITH located the well of Gillett et al in sec. 36, T. 20 N., R. 8 E., Pawnee Co., Okla., which is reported to be good for 1,000 barrels a day in the Wilcox sand at a depth of about 2,950 feet.

W. Z. MILLER, formerly with the Gypsy Oil Co.., has gone into partnership with Mr. Carl D. Smith with an office at 447 Kennedy Bldg., Tulsa, Oklahoma.

C. J. HARES, chief geologist of the Ohio Oil Co., is a frequent visitor at Shreveport, La.

J. ELMER THOMAS has been appointed advertising manager for this bulletin.

The third annual meeting of the SOUTHWESTERN GEOLOGICAL SOCIETY will be held in Dallas, Texas, September 15-16th. The announcement reads: "It has been decided to have as the central idea of the program 'the geological problems of the Southwest' in which some of the larger problems of the region will be discussed. This will involve papers of economic as well as of purely scientific phases of the subject. It is suggested, however, that problems pertaining peculiarly to petroleum be omitted. Aside from this one feature the program will include everything from paleontology to potash, physiography, or ground water." Dr. J. W. Beede, of the Bureau of Economic Geology, Austin, Texas, is chairman of the program committee and R. B. Whitehead, 310 American Exchange National Bank Building, Dallas Texas, treasurer.

BRYAN HENDON is with the Standard Oil Co., of New Jersey and has headquarters at 82 Champs Elysee, Paris.

E. M. CLOSUIT is division geologist for the Gulf Production Co., at Wichita Falls, Texas.

REESE F. ROGERS is geologist for the Texas Co., at Shreveport, La.

GRADY KIRBY and CARL PROBST are working out of the Shreveport office of the Gulf Refining Co.

W. C. EYL, 407 City National Bank Bldg., Lexington, Ky., is publishing a new state map of Kentucky which is far better than any existing map.

JOHN W. TAYLOR is in charge of the geological work of the Gulf Production Co., in the San Antonio district, Texas.

DILWORTH S. HAGER, of the Gulf Production Co., now has headquarters at Houston, Texas.

CARL W. CLARKE has resigned from the Amerada Petroleum Corporation to enter consulting work at Okmulgee, Okla.

"Life of James Hall," is the title of a new book by DR. JOHN M. CLARKE, which may be purchased from S. C. Bishop, 2 High St., Albany, N. Y., at a cost of $3.70 net. It is heartily recommended as a biography which should be read by all geologists.

CLIFTON M. KEELER, who has been appointed a valuation engineer in the oil and gas section of the Income Tax Unit, with headquarters at the Interior Building, Washington, D. C., recently spent some time in Oklahoma on business connected with the Unit.

JOHN CULLEN is assistant valuation engineer in the oil and gas section of the Income Tax Unit, and is stationed at Washington, D. C. His address is 3156 18th Street, N. W.

HENRY A. LEY has resigned his position with the Sun Company at Dallas, Texas, effective May 15, to become chief geologist for the Southwestern Gas Company of Independence, Kansas.

THE OKMULGEE GEOLOGICAL SOCIETY has elected the following officers for the coming year: LOUIS ROARK, *President*, C. A. WARNER, *Vice President*, and H. A. CLARK, *Secretary-Treasurer*.

C. W. TOMLINSON has discovered a new Ordovician hill in Southern Oklahoma in the midst of the area covered by dozens of geologists. This is an even greater accomplishment than the discovery of an oil field.

C. M. BAUER, W. B. EMERY and L. P. ANDRESEN are mapping the Kelvin area in Montana where a new oil field has been opened.

THE LAWTON, DUNCAN, and ARDMORE sections of the Southwestern Geological Society have combined at Ardmore and W. E. Hubbard, J. G. Bartram and Frank Gouin are directing the activities of the section.

D. R. SEMMES, of Tampico, has been in New York City.

WARNER NEWBY is with the Comar Oil Company at Ponca City.

HERBERT SHELTON has left the Buckley interests and is engaged in consulting work at Laredo, Texas.

L. J. YOUNGS is now with the Cosden Oil & Gas Company, at Tulsa.

D. W. WILLIAMS is doing consulting geology at Lawrence, Kansas.

L. G. KEPPLER, formerly with the Carter Oil Company, is with the Southwestern Oil Company at Tulsa, Oklahoma.

W. ARMSTRONG PRICE, formerly with the Transcontinental Oil Company of Mexico, is now with the Humphreys Petroleum Company, at Dallas, Texas.

R. F. BAKER has now become one of the immortals with *Quisque bakeri* named for him by Prof. David Starr Jordan. This imposing name is borne by a Miocene Fish 1-¾ inches long, from a depth of 3,098 ft., at West Columbia, Texas.

G. JEFFREYS is in charge of the developments for the La Pryor Oil & Gas Company, at La Pryor, Texas.

C. L. BAKER has returned from South America and will spend the summer in Texas with the Bureau of Economic Geology.

A. T. WRIGHT is now with the Douglas Oil Company, at Pawhuska, Oklahoma.

W. P. HAYNES is in Roumania.

ED BLOESCH is spending the summer in Switzerland.

J. B. KERR, formerly with the Bureau of Mines, is now with the Carter Oil Company, at Tulsa, Okla.

E. V. WHITWELL and A. G. OLIPHANT are now engaged in consulting geology with offices in the Mayo Bldg., Tulsa, Okla.

E. F. SHEA is now with the Bradstreet Oil Company.

W. W. HENRY is now Treasurer of the Henry Oil Company of Tulsa, Oklahoma.

FRITZ AURIN is in Mexico.

L. G. WELSH, formerly with the Transcontinental Oil Company, has opened an office as Consulting Geologist in the Atco Building, Tulsa, Okla.

DEAN WINCHESTER, who was recently reported in these columns as working for the Standard Oil Company of New Jersey in Brazil, has returned to the United States, and has opened an office as Consulting Geologist, specializing in petroleum and oil shale. His address is 607 E. & C. Bldg., Denver, Colo.

A. E. FATH will spend the summer in Europe.

A. G. MADDREN is in the Argentine Republic for the Carter Oil Company.

C. W. WASHBURNE has moved his office to 2 Rector Street, New York.

R. T. HILL and R. D. GOODRICH have formed a partnership to engage in consulting work with their office in the Magnolia Building, Dallas, Texas.

F. W. GARNJOST is associated with J. G. White & Co., 37 Wall Street, New York City.

H. H. MCKEE and A. D. BROKAW have been engaged in special work at Mexia, Texas.

THE U. S. COAST and GEODETIC SURVEY in cooperation with the United States Geological Survey will establish several gravity stations in Kansas, Oklahoma and Texas during the summer.

D. C. BARTON has made a brief trip to Europe.

HARVE LOOMIS is working in Northern Mexico.

THE UNITED STATES BUREAU OF MINES is mapping Teapot Dome, Wyoming.

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CONSULTING PETROLEUM GEOLOGIST

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